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EDITED BY J. McKEEN CATTELL

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THE SCIENTIFIC MONTHLY

MARCH, 1930

FIVE DAYS OVER THE MAYA COUNTRY

By Dr. A. V. KIDDER

CHAIRMAN, DIVISION OF HISTORICAL RESEARCH, CARNEGIE INSTITUTION OF WASHINGTON

COLONEL LINDBERGH'S recent air survey of the Maya region of Central America is a fine example of the value of team play, for when a great aviator, a great transportation company and a great scientific agency all put their shoulders to the same wheel, that wheel is bound to turn. The project grew from a combination of interests, a focus of attention upon a single objective: Colonel Lindbergh, always keen to demonstrate the utility of the aeroplane and especially intrigued by glimpses, during a former flight, of ancient jungle-buried cities; Pan-American Airways, Inc., spreading its network of flying-trails in Latin America and keen to forward any project contributing to scientific knowledge of and popular interest in the regions it serves; Carnegie Institution, whose staff archeologists had labored earth-bound in the forests for years

FIG. 1. SIKORSKY AMPHIBION, MODEL S-38
SUPPLIED BY PAN-AMERICAN AIRWAYS FOR THE FLIGHTS.

FIG. 2. MAP OF THE MAYA REGION
SHOWING THE COURSE OF THE DAY-BY-DAY FLIGHTS OF COLONEL LINDBERGH'S PARTY AND THE LOCATION OF RUINS OBSERVED AND PHOTOGRAPHED.

longing for the sweeping view of their field obtainable only from the upper air. Such was the team that organized itself during the early autumn for the flights just accomplished.

Belize, once a stronghold of buccaneers, now capital of British Honduras and an important base of the Pan-American, was the rendezvous. We met there on October 5. Colonel and Mrs. Lindbergh were finishing their swing around the Caribbean. Oliver Ricketson, Carnegie Institution archeologist, came down from his headquarters in Guatemala City; W. I. Van Dusen, of Pan-American Airways, and the author flew down from Miami. That evening we laid plans and gathered equipment.

Our general objectives were to test the aeroplane as an agency for archeological exploration in tropical countries and to determine whether or not the ruins of Maya cities could be located from the air. And above all things we

FIG. 3. TEMPLE AT TIKAL, GUATEMALA

THE VERY HIGH PYRAMID UPON WHICH THE STRUCTURE RESTS IS ENTIRELY BURIED IN THE JUNGLE. THE TIKAL TEMPLES WERE USED AS A STARTING POINT FOR THE NORTHERN FLIGHT.

wished to get an idea of what the Maya country really looks like, for in spite of the fact that archeologists have for many years been pushing their way into that region, they have been so buried in the welter of forest, their outlook has been so stifled by mere weight of vegetation, that it has been impossible to gain a comprehensive understanding of the real nature of this territory, once occupied by America's most brilliant native civilization. Such understanding is absolutely necessary, because all people, ancient and modern, are largely products of their environment; hill and plain, watercourse and cultivable land shape the destinies of nations more powerfully than do kings and battles. And of the Maya country as a whole, of the "lay," so to speak, of the land, we have had, until Colonel Lindbergh's flights, only the scantiest sort of knowledge. The labors of many explorers and scientists have, however, given us an outline of Maya history, have made clear the fact that well before the time of Christ there arose in the New World an independent civilization based on the cultivation of corn which culminated at the great cities of the Maya Old Empire. These cities were built and occupied while Europe was in the Dark Ages, but they, like Rome, fell, and their high tower temples and many-chambered palace monasteries were engulfed by the jungle. The Maya people then moved northward into what is now Yucatan, took on a new lease of life and again constructed cities, many of which persisted until the coming of the Europeans put an end to all native American development.

Our problem was clear. We must cover as much of the area as possible, and learn as much as possible about it.

FIG. 4. ANOTHER TIKAL TEMPLE
THE BUILDINGS OF THIS CITY STAND CLEAR ABOVE THE TREE-TOPS AND ARE VISIBLE FROM THE AIR FOR OVER TWENTY MILES.

Our equipment was ideal, a Sikorsky amphibion from the Pan-American fleet, capable of sustained flight with either of its twin motors (Fig. 1). It carried radio, collapsible rubber boat and emergency rations—to which Colonel Lindbergh with characteristic thoroughness saw to it that there was added a shotgun, in case a forced landing made it necessary to live on the country—hammocks, cooking kit, canteens, medicines and machetes.

The general plan was to strike first into the heart of the Old Empire region in northern Guatemala and then turn north to fly the entire length of Yucatan in a single "hop" (Fig. 2). This would necessitate refueling at Merida at the extreme northern end of the peninsula, and as the distance was so great and landing-places were probably non-existent, weight had to be cut to a minimum in order that should one engine fail, the plane could be counted upon to "hold up" for several hundred miles. Van Dusen and I, therefore, stayed behind, and Ricketson, an old hand at Peten travel, was to do the observing.

Taking off from the harbor of Belize the morning of October 6, the course was laid directly up the Belize River, cutting straight across its thousand loops and bends, high above the rapids and shallows that make boat travel so slow. A hundred miles inland the plane turned northward and in a few minutes there became visible the roof-combs of the temples of Tikal, greatest of Old Empire cities (Figs. 3, 4). After circling low for photographs, a straight shot was made for Uaxactun, the oldest known Maya city, discovered in 1920 by Dr. S.

G. Morley, of the institution staff, where Ricketson has excavated for the past four years. From Tikal to Uaxactun is a very long day's journey by mule train, a journey possible at all only if the trail has recently been cleared. The Sikorsky did it in exactly six minutes! Ricketson's clearing and camp (Fig. 5) and the strange, squat, grotesquely sculptured pyramid which he has laid bare were clearly visible, and were photographed as Lindbergh wheeled close above the tree-tops (Figs. 6, 7).

Beyond Uaxactun lay unknown, uninhabited country, and the distance to Merida was so great that no deviation could be made from a direct northward course. The sea of jungle proved to be unbroken. Hour after hour the green floor of the tree-tops flowed back under the speeding plane (Fig. 9). Ninety miles beyond Uaxactun there was made out a flat-topped pyramid surmounted by two temples, the culminating structure of a forgotten and forest-swallowed city.

Northward again over vast stretches of green, until the palm-thatched huts of the first small frontier settlements of Yucatan were reached, and every one breathed a little easier in the feeling that they were again over the homes of living men. Thence onward the towns became larger and the forest was dotted with the clearings of Indian corn-fields, until Merida came into sight and the plane, almost on its last gallon of gasoline, settled down upon the landing field.

The party were overnight guests of Governor Torre Diaz, who has done so much to forward the institution's work in Yucatan. The first objective of the next day was Chichen Itza, largest of New Empire cities, whose temples and

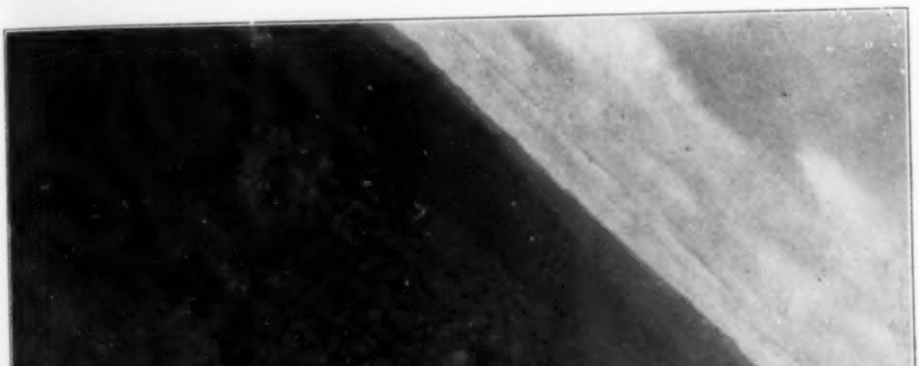

FIG. 5. CARNEGIE INSTITUTION'S EXCAVATION CAMP
AT UAXACTUN, GUATEMALA. THE PLANE BANKED AT THE INSTANT MR. RICKETSON TOOK THIS PICTURE.

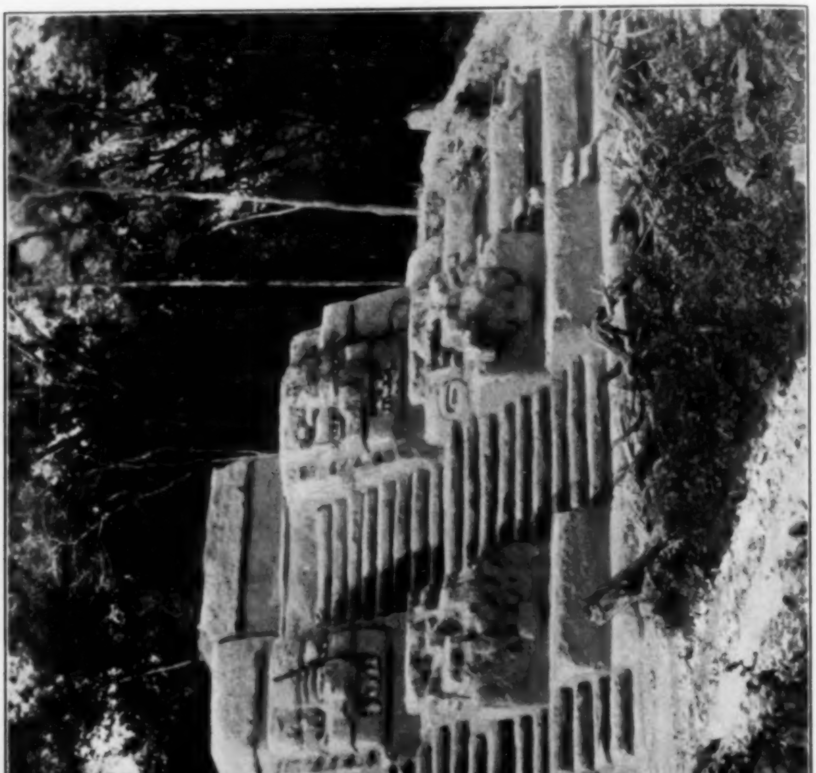

FIG. 6. GROUND PHOTOGRAPH OF THE UAXACTUN PYRAMID

THIS REMARKABLE STRUCTURE, THE OLDEST KNOWN EXAMPLE OF MAYA ARCHITECTURE, OWES ITS SPLENDID PRESERVATION TO THE FACT THAT IT WAS BURIED IN ANCIENT TIMES BY THE ERECTION OVER IT OF A LARGER PYRAMID, WHICH WAS REMOVED IN 1927 BY MR. RICKETSON'S PARTY.

FIG. 7. STUCCO PYRAMID AT UAXACTUN
WITH TRENCHES IN THE PLAZA IN FRONT OF IT.

pyramids, cleared by the Mexican government and by the institution under Dr. Morley's direction, showed snow-white against the green "bush" (Fig. 8). Thence southward to Belize, east of the outgoing route, across country hitherto untraveled, country so densely overgrown that no trace of ruins could be discerned.

The flights of the first two days covered nearly 850 miles, much of it over regions never traversed by white men and none of it ever seen from the spreading view-point of the air. At our conference on the evening of the return to Belize we decided that we must train ourselves more fully to recognize tree-shrouded mounds and pyramids, to pick out from above the vague, masked outlines of plazas and temples. And so on the eighth we struck again for the Peten and searched for ruins whose general location was known. In this way there were picked up Yaxha and Nakum, and by repeated low circling we taught ourselves this new technique of sky-spying. Thence off again to Tikal and Uaxactun, eastward to what we believed to be a ruin that could be seen on the skyline from above Uaxactun, but which turned out to be merely a group of large trees; and so to the Laguna de Peten (Fig. 10), where the Guatemalan outpost town of Flores crowds a tiny island in the lake. We paid our respects to the governor, who came out in a launch to greet us, surrounded by the entire population in dug-out canoes (Fig. 11), and then rose to fly southward over a vast flat stretch of alternating savanna and woodland, toward the northern tributaries of the Pasion River. These streams traverse a terrible and (to fly over) a most terrifying country (Fig. 13), a confused

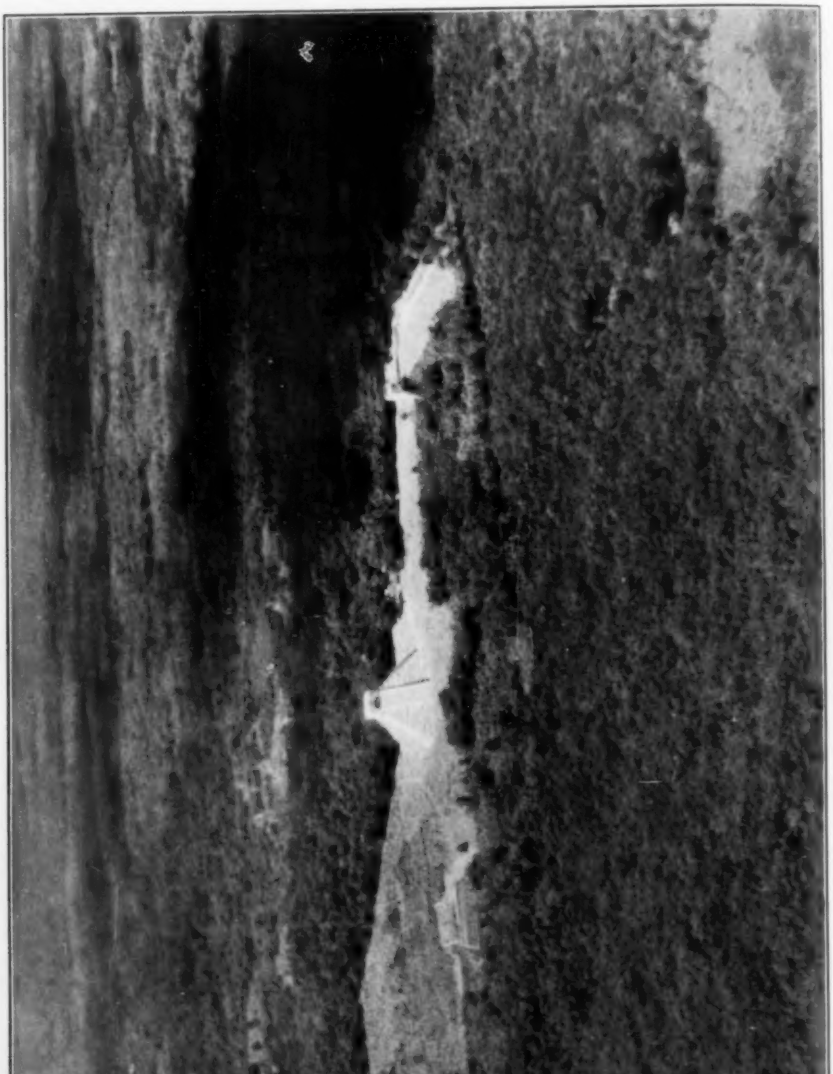

FIG. 8. RUINS OF CHICHEN ITZA FROM THE AIR

NOTE THE VERY CHARACTERISTIC TEMPLE-TOPPED PYRAMID "EL CASTILLO."

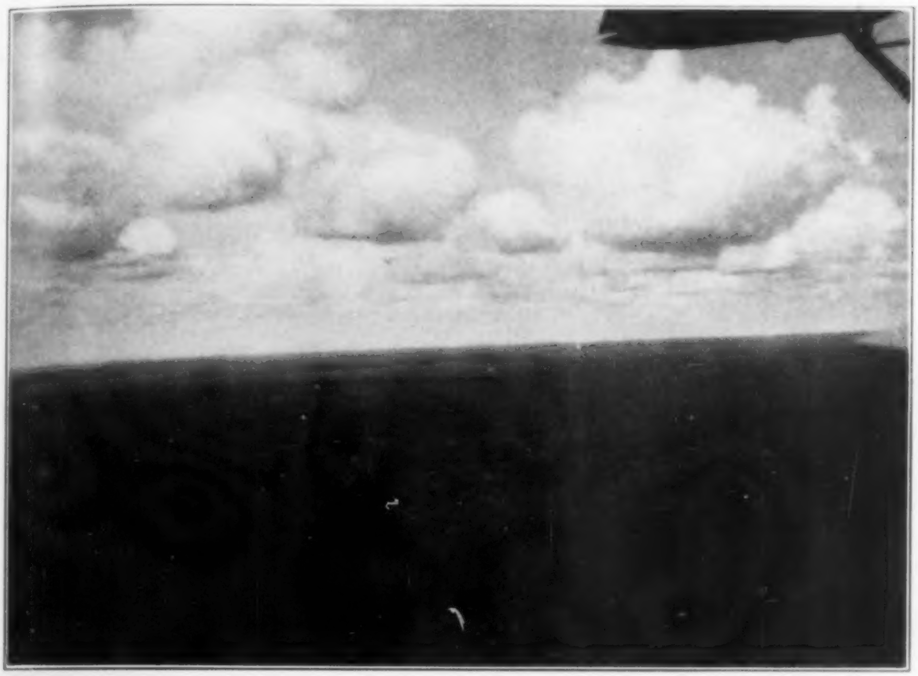

FIG. 9. THE GREAT PLAIN LYING NORTH OF UAXACTUN
A REGION ENTIRELY UNEXPLORED SAVE BY THE AIR CROSSING OF OCTOBER, 1929.

welter of gorges and limestone pinnacles smothered in a jungle so dense, so intertwined, so utterly hopeless to penetrate save through the foot-by-foot hacking of trails, that I think no one of us failed to give a sigh of relief when we soared over an outlying spur of the Cockscomb Mountains, dodged between two rainsqualls and saw to the eastward the silver shine of the sea.

The next few minutes brought one of those incredible transitions possible only to the air traveler. We swung to the north, dipped across the coastline and took the smooth water at a little key miles out in the Gulf of Honduras; anchored the plane, pumped up the rubber boat and rowed ashore. A half hour after being over that ghastly, broken, interior wilderness, we were comfortably cooking lunch under the palms by the coral beach.

The fourth day we took off a little after ten, passed northward over the coastal swamps, turned inland and in an hour were beating across the jungle west of Lake Bacalar, where, thanks to our practice of yesterday, we were able to pick up three sets of mounds, one of which was evidently the center of a very extensive city. There were four high pyramids, upon two of which could be glimpsed the white walls of temples. Colonel Lindbergh then climbed to two thousand feet and headed north across the great flat plain of Yucatan. There were no hills or valleys to break the even spread of the tree-tops, and we at once began to see the sharp eminences of ruins. I quote from the air-notes:

Sharp pyramid on N. horizon (12.05); small lakes to N. (12.07); another small lake about 6 mi. E (12.16). Now coming over pyramid (it was visible 20 miles away)—group is of

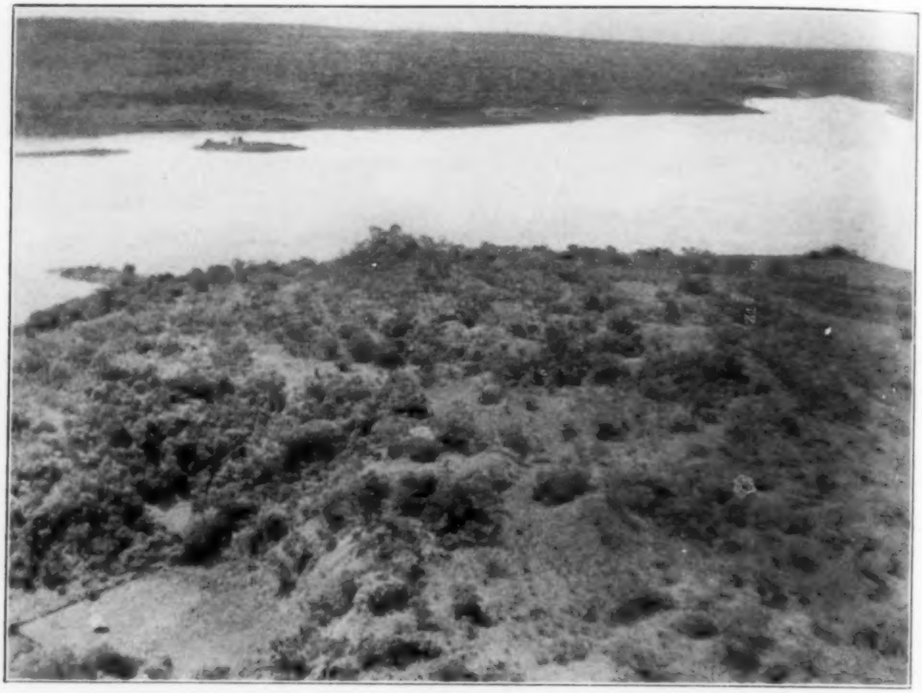

FIG. 10. LAKE PETEN SEEN ACROSS TAYASAL PENINSULA
MOUNDS OF MAYAN CITY OF TAYASAL IN FOREGROUND.

one large pyramid with three smaller ones 100 yards E. of it on a plaza (?). Indian village (6 palm-leaf huts in clearing) just (2 mi.) W. (12.20) Off N., bush dry and gray, low, and can see ground now and then between trees. High bush seems to have ended at last site. (12.29) Circled low over Indian huts, people running into houses and into bush. (12.35) Six-house village. (12.37) Bush dry and deader looking than ever, think some of these trees must shed leaves at this season. Small rain-squalls all about. (12.39) Large low mound directly below in Indian clearing. (12.43) Turn due W. toward high pyramid sighted by Mrs. L. and now heading for it across uninhabited country. (12.49) Another pyramid to N. of first one.

These groups, most of which are probably new, were located by compass-course and flying time and in some cases further marked by bearings on distant landmarks.

And so on. For an hour or more we tacked back and forth, noting sites in all directions, flying close over the largest ones and gradually working north until we saw poking up on the horizon the enormous mounds of Coba. By one-thirty we were over it, anxious to land on one of the two little lakes about which the great forest-buried buildings are grouped, for Coba has been visited by less than a dozen white men. We dipped and skimmed the water, but Colonel Lindbergh shook his head at the high trees on the farther shore and we rose again to circle the tall *castillo* and cross in a split second a swampy lowland that three years before had cost Eric Thompson and me a full hour of bitter, sweating struggle.

Up till now every one had been too busy to think of lunch, but when we swung high again and headed for the coast Mrs. Lindbergh produced choco-

late, crackers and coffee, and by the time we alighted in the ocean to go ashore at the seaside ruin of Tuluum (Fig. 12) we were well fed. That night we spent at Cozumel Island, where the Pan-American has a base, revisited Coba the next morning to recheck our observations and by ten o'clock were headed for Cuba, Miami and home.

During the flights every one was constantly busy; Colonel Lindbergh with the map on his knees kept track of courses, wind-drift, and estimated distances to and between objects sighted; Mrs. Lindbergh, whose eyes are very keen, watched the bush like a hawk, and took the photographs; Van Dusen, through Ehmer, the crack radio operator, sent bulletins of progress to the Pan-American bases at Miami and Belize, while Ricketson and I filled notebooks as fast as we could write, jotting down observations on topography, nature of forest, occurrence of lakes, streams, swamps and descriptions of the appearance from the air of the ruins passed over. The greatest thrills of our five days' flying came, of course, from the finding of hitherto unrecorded groups of Maya buildings indicating the presence of ancient cities. But the purpose of the expedition was much more than the mere discovery of sites. It was planned and carried out as a test, a reconnaissance, to gauge the value of the aeroplane for survey and observation work, and it proved that the plane is of unique usefulness in enabling one to study the country as a whole, to record its geography, to note the nature, distribution and extent of its forest types and to plan routes and fix landmarks for ground exploration. Finally, it is certain that the plane can in many regions

FIG. 11. PEOPLE OF TAYASAL

CAPITAL OF DEPARTMENT OF PETEN, GUATEMALA, COMING OUT TO THE PLANE IN DUGOUT CANOES.

FIG. 12. RUINS OF TULUUM ON THE EAST SIDE OF YUCATAN

NOTE WATCH-TOWERS AT THE CORNERS OF THE GREAT MASONRY WALL ENCLOSING THE TEMPLE AREA.

FIG. 13. BROKEN COUNTRY SOUTH OF LAKE PETEN
A HILLY REGION COVERED WITH DENSE JUNGLE AND OFFERING NO POSSIBLE LANDING PLACE.

serve to transport, set down on lakes or savannas and pick up again small parties of workers, thereby enabling them safely and easily to cover in weeks territory which would require months and whole seasons of difficult ground travel.

MODERN ASTRONOMY AND THE PROBLEMS OF STELLAR EVOLUTION

By Professor C. D. PERRINE

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THE ultimate object of pure astronomical investigation is to determine the form, motions and physical constitution of our universe, in the broadest sense. Even its limits are unknown and no serious scientist would be so bold as to attempt to set them any more than he would to the ultimate form which man himself will acquire under the influence of evolution.

Evolution plays its part in the acquisition of knowledge of our universe as truly as in biology, although of course not in the same sense. The ancients first occupied their awakening scientific intelligences with the geographical features of their immediate neighborhoods and very naturally concluded that the earth was flat, which conclusion brought a large crop of difficulties when they tried to explain the motions of the Sun and Moon.

When they became more observant and took thought of the apparent forms of the Sun and Moon and of drops of water they were led to the true explanation of a spherical form for the Earth as well as for the Sun and the Moon.

With the invention of the telescope a new era was opened. Not only were new worlds revealed but almost as startling an array of new facts about the known heavenly bodies—spots on the Sun, markings on and circular forms for the planets and moons revolving around them. Saturn was seen to have a wide flat ring around it. Two new large planets, Uranus and Neptune, were discovered. Stars were multiplied by thousands, and they were seen to be of all colors. The few nebulous spots visible to the unaided eye were also increased to thousands. Structural details were observed in the bright comets, and comets so faint that they could not be seen without a telescope were found to be more numerous than bright ones.

The ring of small planetoids was discovered. Stars were seen to be double and multiple, and groups containing thousands were revealed.

Graduated circles were added to the telescopes and more accurate positions of all heavenly bodies obtained. The screw and the spider thread were brought into play, and the diameters of planets and small distances between stars and other objects were determined with accuracy.

More light was necessary to see faint objects better, and with the larger telescopes still fainter objects were discovered until we have the giant telescopes of to-day.

The dispersive power of the prism was applied to the analysis of light and we have the spectroscope, one of the most powerful and far-reaching aids to astronomy as well as to physics. The addition of photography may be said to have rounded out the mechanism for a complete reorganization of astronomical investigations.

The history of these advances is of great interest but can only be mentioned here. Neither is it possible to detail the growth of and attempts to solve the larger problems in the earlier epochs of astronomical research.

These new methods of research have now been in extensive use for nearly a half century, and the results have been so illuminating that it is possible to revise earlier hypotheses and to formulate some new ones.

As the most recent developments and those of greatest general interest have been in the great outer universe of the stars and nebulae I shall refer only briefly to the origin of the solar system.

The great work of Copernicus, Kepler and Newton placed the solar system upon a firm gravitational basis, one which stands to-day unshaken. Its origin and mode of evolution are, however, still wrapped in nearly impenetrable darkness. Of the various attempts to explain it the Laplacian nebular hypothesis has received the greatest attention and confidence. The last quarter century, however, has confirmed doubts as to its sufficiency. Laplace assumed his original nebula to extend to the outer confines of the system and to be rotating essentially as a solid body. That condition introduces the moment of momentum as a test of the hypothesis. Chamberlin and Moulton have investigated this question and find that instead of being constant in the solar system as it should be on Laplace's hypothesis, the Sun possesses only one two-hundredth part of what it should be as calculated from the outer planets.

This test is crucial and shows that the hypothesis can not be true. Chamberlin and Moulton proposed their alternative theory of the near approach of two stars and the tidal ejection of spiral arms which condensed into the planets and satellites. This hypothesis satisfies the moment of momentum test and the other observed conditions as far as known.

It has the strong argument in its favor that near approaches of stars must occur, and the prevalence of the spiral form among a certain class of the nebulae shows that some such tidal deformations do occur. In this connection it should be borne in mind, however, that no true star has been observed with such spiral arms, unless we except the planetary nebulae which show streams and structure which may be spiral, and that true spirals are nebulae of vastly greater proportions and masses than ordinary stars.

As the spiral nebulae contain by observation thousands of stars it is not rational to assume them as a class to be the progenitors of small systems like our Sun.

The planetary nebulae are now known to be composed of essentially a single star surrounded by shells and streams of nebulosity.

Investigations of the spectra of these planetary nebulae by Campbell and Moore, of the Lick Observatory, have shown that some at least of such nebulae are in rotation. In some of them the forms are quite irregular and even some sort of spiral arms can be traced.

An investigation just concluded in Córdoba of these observations shows the strong probability that the observed radial velocities of these nebulae are largely of expansion and contraction and not wholly of translation. If this conclusion is confirmed as seems probable the original Laplacian hypothesis may be modified to satisfy the observed conditions in these planetary nebulae.

There is considerable evidence to show that the planetary nebulae are the more or less stabilized conditions of the class known as temporary stars or novae. Without going into details, the most plausible hypothesis of the cause of these outbursts (and therefore probably of the planetary nebulae) is a grazing collision of a small cloud of cosmical matter with a stellar body.

If such an assumption is correct we have in the planetary nebulae potential solar systems. For such a mode of formation as that outlined provides the central sun with a small moment of momentum and the mechanism for the formation of planets and satellites with larger momenta of momentum.

Further work will be necessary to decide, but the evidence at present available favors, in my opinion, the hypothe-

sis that the planetary nebulae are the forerunners in general of solar systems such as ours. This is not necessarily, however, the only possible mode of their origin, and it may be that there are others.

The Observatorio Nacional Argentino was founded at one of the most important epochs in the science of astronomy. In the decade previous photography had been applied to the fixing of lunar detail and the positions of the stars' images automatically and free from personal bias. The advantages were obvious, and with the invention of the dry plate this method was at once applied to many problems. One of the largest pieces of work undertaken was the Carte du Ciel, a stupendous undertaking which is not yet completed. Another of more modest dimensions was the photographic Durchmusterung by Gill at the Cape Observatory and Kapteyn at Groningen, Holland. This work was completed rapidly and has been most useful.

At about the same time the spectroscope was being applied to the study of the Sun and stars in several countries, notably England, France and Germany as well as by Father Secchi in Italy. The new science of photography was applied to this new branch of astronomy also and soon proved its value. De la Rue and Lockyer in England and Janssen in France applied it to total solar eclipses with the discovery of helium by Lockyer as one of the results. Huggins especially in England applied it to the study of stellar and nebular spectra with most important results—among which was the discovery of the bright lines of the gaseous nebulae.

A little later Vogel in Germany applied photography to the spectra of the stars for the determination of their radial velocities by means of displacements of lines from the positions which such lines have when the observer and the star observed are at rest with respect to each other (the Doppler principle).

Thus it may be truly said that photography has revolutionized astronomy not only by opening up new fields which could be observed only in that way but also by its application to the determination of the positions and motions of the stars from photographic negatives which previously had been determined only by the meridian circle or equatorial (micrometer).

Not only does photography give a more rapid and accurate record of considerable areas of the sky, for example, but it also permits the observation of objects too faint to be seen with any telescope simply by increasing the exposure time. The longer the sensitive plate is exposed in the telescope, the fainter the stars and nebulae that will leave an image. And the records are permanent and may be consulted decades hence.

Many of the objects photographed today have never been seen by the human eye except on photographs. Satellites, minor planets, comets, thousands of nebulae and millions of stars have been discovered in this way, and many facts concerning all sorts of celestial bodies have been made known which would have been impossible in any other way.

As I have already pointed out, Gould's first object was the preparation of the catalogues of positions of the southern stars which were so badly needed. But he also recognized the importance of the new method of photography and applied it to the problem of the study of the motions of star clusters by taking a series of photographs of thirty-eight of the most important of these in the southern sky and measuring the positions of the stars composing them. These observations furnish an invaluable basis which together with observations at the present time will be used to determine their

motions both internal and of translation as a whole.

The preparations of the catalogues and charts proved of such magnitude that but little time was available for photographic work outside the astrographic program, and no attempt was made until recently to enter the astrophysical field. As the work on the older programs drew to a close it became possible to make plans for a large reflector with which to make suitable observations both spectroscopic and photographic of stars, and particularly of the nebulae, in the southern sky. Plans were made and funds provided in 1912 by Congress through the effort of Minister Garro and President Saenz Peña for a reflector of one and one half meter aperture. The dome was delivered as well as the glasses for the mirrors and the mounting ordered just before the war began. It was, however, impossible to finish the telescope and put it into use. Work has now been resumed on the building, and it is hoped to have the telescope in use toward the end of next year.

A reflector of 75-cm aperture of short focus especially for work on nebulae was constructed in the observatory shops and put into use in 1917.

Some valuable observations of nebulae were secured with it, but as it was mounted in one of the old domes the demolition of the old administration building in 1923 and the construction of a new one interrupted the work. A new dome is now ready, and as soon as the telescope can be mounted, work will be resumed with it.

A lamentable accident has temporarily delayed the mounting of this telescope, in which, by the breaking of the lifting apparatus, a most estimable and efficient member of the firm constructing the dome lost his life and a part of the telescope was damaged.

The advances made since the application of photography and the spectrograph to astronomy have been so rapid that the solution of many problems has been made possible and old problems have received new interpretations. The subject is too large to attempt to treat adequately in a single paper. All I can do is to give a brief outline of some of the problems and progress up to the present. Upon an understanding of these problems depends a rational formation of plans for observations to solve them.

The problems which could be investigated with advantage by the positions, motions and brightnesses only of the stars and nebulae were limited to the form, structure and internal motions of our stellar system and these only superficially. Such observations together with the law of gravitation furnished the means of determining the sizes and orbits of the bodies in our solar system with a high degree of accuracy. Thus the problem of the sizes, distances and motions in the solar system may be said to be satisfactorily solved.

The problem of the origin and constitution of these bodies is far more difficult and is closely allied to similar problems of the stars. Little definite progress on these was possible before the introduction of the spectroscope, with which the substances composing them could be determined. The analysis of their light not only showed that the planets shone by reflected sunlight and proved the presence of practically all terrestrial elements in the Sun and stars but it also permits of determining the velocities of such bodies toward or away from the observer and other facts which have been of the highest importance in the interpretation of our universe. These facts are such as could not be discovered from the old methods of observation, but in connection with those permits the study of entirely new problems as well as aiding greatly in the solution of the older ones.

For example, the spectroscopic observations have aided by combining these radial velocities determined with the spectroscope with the tangential motions derived from the old observations of position.

Such radial velocities observed with the spectroscope enabled Keeler to prove that the ring of Saturn is actually composed of small bodies, as had been concluded to be the case by Clerk Maxwell from theoretical considerations, and was not a solid or liquid body rotating as a whole. His observations of the spectrum showed that the *inner* portion of the ring was rotating faster than the *outer* portion, which would be the case if it were composed of small bodies and the reverse of what would be the case if it were rotating as a solid.

By means of similar observations the periods of rotation of some of the planets upon their axes have been determined and some of the planetary nebulae and globular clusters of stars found to be rotating.

By the same means the temporary stars which flash out so suddenly are found to be in great activity and sending out shells and clouds of hot gases with tremendous velocities.

Perhaps the most startling feature discovered by this means, however, is the very high and generally outward velocities of the spiral nebulae.

There are many interesting questions in connection with the progress of modern astrophysical problems, but time permits a consideration of some of the most important only. Attention will be confined therefore to the stars and nebulae.

Consideration of the stars comes first, naturally, although the ideal is held always in mind of connecting all evolutionary problems finally into one all-embracing explanation of everything.

Two exactly opposite hypotheses to account for the origin and evolution of the stars have found favor.

While Laplace's nebular hypothesis was formulated specifically to account for the secondary bodies of the solar system, it has been applied also to the condensation of the stars from a primitive gaseous nebulous mass and met with general favor until recently.

Its course is from a large, hot mass of gas to a cool and possibly solid comparatively small body.

Opposed to this is the well-known hypothesis of Lockyer which assumes an origin in a large, extended and cool cloud of cosmical matter which by condensation becomes hotter and brighter and whiter for a time and then loses more heat by radiation than it gains by condensation until it becomes faint and red or perhaps even cold and dark. Lockyer's hypothesis was not looked upon favorably until recent years but is now generally accepted. It does not provide for the gaseous nebulae, and this may be the principal reason why it was slow in meeting with favor. A plausible explanation has been found, and the stars and gaseous nebulae can now be accounted for in a single hypothesis.

The application of spectroscopy at once showed wide differences among the stars, which were accompanied by differences in color apparent to the eye. These different spectra were finally arranged in a sequence and lettered O, B, A, F, G, K and M, in which the O and B type stars are blue and white with only a few lines, generally of hydrogen and helium. The lines of other substances become frequent from A type to M, and the colors change through yellow and orange to deep red in the M type stars.

These differences of color and spectrum are now known to be due to differences of temperature, the blue and white stars being very hot and the yellow and red stars relatively cool.

We have now to consider the distribution in the sky of these different spectral

classes which undoubtedly is an important factor in any hypothesis as to their relationships. The F, G, K and M type stars are fairly evenly distributed over the sky, but not so the O, B and A type stars. These types have a strong preference for the region of the Milky Way. The A type stars begin to show such a preference which in the earlier subdivisions is very marked, a preference which becomes more marked in the B class stars and still more marked in the O type stars. These latter are confined to a narrow belt along the center line of the Milky Way, and their spectra show great activity and high temperatures.

The gaseous nebulae and temporary stars show a marked preference also for the Milky Way.

Such preferences as these indicate strongly if they do not establish that their spectral conditions are due in some way to conditions existing in the Milky Way—external to the stars themselves. These facts and the behavior of the temporary stars which successively pass through the B, O and nebular conditions led me some years ago to propose the hypothesis that these spectral types resulted from the cosmical matter which is known to exist in the Milky Way in large quantities. Under such conditions any stars would sweep up such matter as a result of gravitation and increase the temperatures of their surfaces, the amount of increase depending upon the amount of matter swept up. This hypothesis is based wholly upon well-established facts and physical laws and is entirely logical and extremely simple. It is not contradicted by any known fact and fits in well with the general hypothesis of Lockyer.

Recent investigations tend still further to confirm it by explaining the large radial velocities of the O type stars and planetary nebulae as motions of expansion and contraction of their surface layers and not wholly motions of these bodies as a whole. It had been noted previously that the large gaseous nebulae had very small velocities and that the velocities of the stars increased gradually from B to M types. From this it was inferred that the velocities of the stars increased with age, but left the O type stars and the planetary nebulae as anomalies. If these large velocities are confirmed as expansions and contractions all now fall into a regular progression in velocity as well as spectral type and temperature, whichever direction is assumed for the changes.

Until comparatively recently all nebulous-looking objects had been classed together, although differences of form and color had been noted which led to the separation of the so-called "white" nebulae into a subclass which afterward proved to be largely spirals. When radial velocities of the nebulae were obtained by means of the spectrograph it was soon noted that these spiral nebulae had on the average high velocities, about fifty times the average velocities of the stars and other nebulae, and that with few exceptions they are of *recession*.

This at once placed them in a unique position and opened up new problems as to their origin and relationship to the stars and other bodies of our stellar system.

Previous investigations had shown them to be composed, in many cases at least, of thousands of stars, which in connection with their peculiar forms led to the hypothesis that they were separate universes more or less like our own.

Recent investigations, however, at the Observatorio Nacional Argentino have shown relationships of their motions which can be explained only as in some way connected with our system. The brightness of the stars which have been observed in the larger of the spirals is crucial evidence that, although distant, they are nevertheless within the confines

of the galactic system. These relationships are of unusual interest and will be referred to in some detail.

The origin of these spiral nebulae has been even more uncertain than the stars. At least a guess could be made as to the origin of the stars based upon a few well-established facts, as witness the hypotheses of Laplace and Lockyer. But not even a reasonable guess could be made as to the origin of the spiral nebulae, as scarcely a physical fact was known until the spectroscope showed what appears to be a stellar constitution and predominantly high velocities of recession.

These two conditions in connection with their observed forms now permit a certain amount of reasonable speculation.

The spectra of a considerable number of spirals have now been accumulated and are found to be practically those of stars about like our Sun. This fact in connection with the stellar points observed in many of the larger ones seems to establish the fact of a stellar constitution and also that they contain many thousands of times the amount of "matter" in even double stars. This at once separates them from the individual stars and gives them a status as systems of a higher order, but still dependents of the main or galactic system.

The high velocities revealed by the spectroscope also separate the spiral nebulae from the ordinary stars.

These high velocities more than any other feature require an explanation. Recent attempts have been made to explain them on the ground of some form of relativity effect. Such attempts are not well founded, in my opinion, because a consideration of these velocities in detail shows a wide range and that some of them are even *approaching*.

Their reality is still further indicated by relationships to angular distance from the Milky Way, to size and also to their apparent elongations, which have just been discovered in Córdoba.

Because of their high velocities it was suggested several years ago that the "matter" composing the spirals had been originally ejected from the stars of our galactic system and had been gathered together in its distant parts. If this were true these velocities should show some relation to the plane of the Milky Way, those spirals near the poles of this plane having greater radial velocities than those in the direction of the Milky Way. Observations of nearly fifty spirals were available, enough to give confidence in the result. These showed a strong relation of this kind.

During the progress of that investigation it was observed that the smaller spirals had in general larger velocities than the large ones. Also that those turned edgewise had higher velocities than those appearing round or nearly so of the same size. A preliminary examination was made and gave positive results.

Then because of so many relationships mathematical solutions were made to determine them as well as the solar motion which had been ignored, simultaneously. These results fully confirmed the preliminary ones and are given in a paper appearing in the *Anales* of the Sociedad Científica Argentina.

The dependences upon size and inclination appear to be of especial importance.

It was found that the dependence upon size was not linear but inversely as the square root of the apparent diameters. Investigation of actual size by means of Cepheid variables and the brightest stars in eighteen nebulae indicated that the dependence upon size was not upon distance, at least not entirely. If this dependence is wholly upon actual size we have the surprising result that the inverse of the square root of diameter multiplied by the velocity is a constant.

If the constitution of these bodies is the same their masses would vary ap-

proximately as the second power of their diameters, because they are very thin in comparison with their diameters and we would have their masses multiplied by their velocities constant. In other words, their momenta of momentum or total amount of energy would be constant, a condition which has been suggested by some investigators as existing among the ordinary stars from the fact that large and massive stars in general have small velocities and the high velocities are almost invariably found among stars which are believed to be small.

Einstein has formulated the hypothesis that mass multiplied by velocity is constant and limited by the velocity of light. If the dependence of the velocity of the spirals upon size is fully confirmed as a dependence upon mass the possibility is opened up that the resulting equation is not limited to the velocity of light. The consequence of such an equation being true to the limits would be that a mass infinitely large would have no velocity and that an infinitesimally small mass would have an infinite velocity.

In other words, such a condition would lead to the conclusion that matter was only a form of motion.

Such a conclusion would have very far-reaching effects and lead to a drastic revision of some of our ideas, especially as to the so-called elements, the motions of the heavenly bodies and evolutionary processes in the organic world. But it must be emphasized that as yet such thoughts are as speculative as relativity.

The dependence of velocity of a spiral nebula upon the inclination of its plane to the line of sight is in harmony with a dependence upon size, and is in fact a necessary consequence of such a dependence if their mode of formation is found to be what appearances suggest.

The only known method by which such spiral forms can be produced is by the near approach of two bodies as outlined by Chamberlin and Moulton in their planetesimal or spiral hypothesis. The study of many spiral nebulae leaves no doubt that this is the correct explanation of the origin of their forms. It is not necessary to give the entire reasoning. It is sufficient to point out that many cases are known of pairs which appear to be related, and to one in particular, M 51, which shows the disturbing body attached to one of the spiral arms.

Such a dependence of velocity upon inclination as that found in which those whose planes are in the line of sight have larger velocities than those seen at right angles to their planes follows naturally from the near approach and union of two bodies of different velocity but in the same direction, *if their masses are different but their moments of momentum equal or greater than the ordinary effect of gravitation between them.*

This would seem to be in its turn evidence favoring the reality of the dependence upon size and the interpretation placed upon it.

The results enumerated above together with other investigations in hand of the B and A class stars suggest a general hypothesis as to the principal relations and the current evolutionary processes among the stars. No attempt is made to account for the beginning and only an outline can be given. The present state of our knowledge does not warrant anything more.

The course pursued by the stars which seems to satisfy best the observed facts and to be more or less cyclic is that they originate in clouds of cosmical matter as postulated by Lockyer.

By condensation heat is generated which is not radiated away as rapidly as generated, probably due to a blanket of atmosphere, perhaps largely of calcium. The temperature rises until the F, or late A, type is reached where the heavy envelop has been absorbed and radia-

tion exceeds the heat generated by condensation, the surface temperature falls and the spectrum changes in the reverse through G and K types to M.

This is the normal course if undisturbed by additions of matter or energy. (It is difficult to see how any large, sudden *diminution* could take place.)

In the Milky Way regions, however, where cosmical matter is known to be plentiful, encounters with clouds of varying sizes and velocities will cause rises of temperature, some slow, some sudden, and these will be accompanied by changes of spectrum.

If the accretion of energy is slow and of small amount the change of spectrum will also be slow and small and we will have stars of early A type only. A larger accretion will produce the B type of spectrum. Still larger accretion will produce the O type. Sudden encounters with small clouds, at high speeds, will account for the temporary stars, and if these are of sufficient magnitude planetary nebulae will be produced.

If the encounters are with clusters of stars, large irregular nebulae such as those of Orion and Eta Argus will be produced. In all these nebulae are seen the streams and clouds of dark, cosmical matter which have been instrumental in causing the outbursts.

The climax appears to be reached in the production of gaseous nebulosity, after which condensation begins and the spectrum and appearance change as in the large nebula M 8 and in some of the planetaries.

Whether there are still higher stages of activity than the nebular stage is not known. One is inclined to suspect that there are higher stages but that our means of observing are at present inadequate to detect them because of the limit set by our atmosphere to the observation of short waves and perhaps also because the eye is incapable of seeing light of very short and very long waves which are revealed by the spectroscope. Such a possibility receives added weight from the very high velocities of the spirals which require an explanation not as yet forthcoming.

This is essentially the hypothesis of Lockyer modified to include what I conceive to be an offshoot occasioned by conditions existing in the Milky Way which account for the objects with strong preferences for or confined to those regions—the A, B and O type stars, the gaseous nebulae and novae.

Speculation on the beginning of all things and an end or the possibility of a regeneration and cycles offers a fascinating field—but one in which not only an imagination of a very high order is necessary but also an extraordinarily well-balanced judgment to discover the most important facts. A genius could not avoid all the pitfalls in such unknown fields.

And yet real progress is impossible without some plan to work to, even though it may be wrong.

No observed fact raises so strongly the question of infinity of time and space as does that of the high velocities of the spirals. What becomes of this matter or energy? They appear to be beyond gravitational control.

The relativists suggest that these high velocities are not real but a result of curvature of space. But when we are asked to believe that nebulae should be seen twice, on opposite sides of the sky, one seen direct and the other as a result of their light going around the curved way, evidence of a higher order than any given to date is demanded.

But some answer must be found to the question whether such velocities lead to infinity or merely to a regeneration in the outer spaces in the cosmic rays of Millikan, for example, and it is conceivable that the works of the relativists are gropings which will one day discover edible fruit.

I have adverted to the large number of interesting problems now demanding

attention and the impossibility of even mentioning many of them. I will, however, refer very briefly to three which have occupied some attention: (a) periodic phenomena especially noted in the variable stars, (b) the preferential motions discovered by Kapteyn and especially the to-and-fro motions among the stars and (c) the origin of double stars.

Studies of stars varying in light, especially those of short period, showed a tendency for certain types of variation to occur at certain periods and for the amount of variation to be greater at certain periods also.

Preferences for certain periods were also found among the so-called "spectroscopic binaries" whose radial velocities have been found to vary periodically and a further tendency was observed for the lengths of these periods to be arranged in several series which are related by the factor 1/2 or 2. Similar preferences for certain periods, some of them of the same lengths, were also found among the planets and satellites of the solar system, as well as indications of the factor 2.

These relationships require much more study. If fully confirmed the important conclusion is indicated that periodic phenomena, whether of orbital motion or pulsations, are closely related. This in turn would point to some very fundamental underlying condition of matter or energy.

The conclusive evidence which has been discovered that the spiral nebulae belong to our stellar system has suggested a possible explanation for the preferential motions among the stars discovered by Kapteyn and also for their general to-and-fro motions. It is that the stars nearest, perhaps the naked eye stars and somewhat fainter ones, belong to what was once one of these auxiliary systems. It is obvious that the observed stellar motions could be fitted to such a system.

The problem of the origin of double stars has never been settled. Two hypotheses have been advanced: (1) That a single body separated by fission as a result of rotation and elongation. This hypothesis is generally favored and much theoretical work has been done upon it. It is far from convincing, however, as the only known conditions would produce a contrary result. No evidence of weight is forthcoming to produce such accelerations either of rotation or elongation as those demanded. (2) That they have resulted from capture. This theory has in its favor the certainty that near approaches must occur. If these occur in the early stages when stars are believed to be very much extended or perhaps in the cosmical cloud condition, the mechanism is provided for capture.

Evidence favoring the hypothesis of capture has recently been found in the motions of these double stars. If the components originally had motions in all directions, it seems probable that on the average the resulting pairs would have smaller velocities with respect to the galactic or parent system than single stars.

A preliminary investigation of radial velocities and proper motions does in fact indicate smaller motions for double stars than the stars in general, thus appearing to favor a theory of capture.

The foregoing are some only of the very interesting problems which astronomers are trying to solve with respect to the great universe of which we are a part—a very small part only. The Observatorio Nacional Argentino has reached a period in its existence where it is possible to devote a portion of its energies to observations of stars and nebulae in the southern sky to aid in the solutions of some of these problems. A few observations have already been made with the apparatus and time available. With the large reflector now nearing completion it is expected to take a larger share of such work—observations which are badly needed of southern objects.

SOME RECENT CHANGES IN OUR ATTITUDE TOWARDS THE NATURE OF THE PHYSICAL WORLD

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WHENEVER I see a popular or semi-popular book on atoms, electrons, energy or distant universes, an old story comes to my mind written by a Russian humorist and purporting to be an extract from an ancient chronicle. It runs somewhat as follows: One evening a famous philosopher was sitting on the steps of his house, contemplating the stars. A passer-by reverently approached him and said, "Tell me, oh wise man, how many stars are there in the sky?"

"You lown-down ignorant rascal," answered the philosopher angrily, "who can encompass immensity?" And the passer-by, honored by a conversation with the sage, and pleased and satisfied with the answer, went on his way rejoicing.

True, modern writers on the physical world are more polite and evasive in their statements, and perhaps for this reason the readers are not nearly so well satisfied as the ancient passer-by was.

During the past thirty years the progress in physics, chemistry, astrophysics and astronomy has been tremendous, perhaps equal to or exceeding that of several preceding centuries. Human curiosity is also greater than ever, and the man in the street is anxious to learn, without spending much time or effort, what this wonderful progress consists in. It is true that in order to understand in general the present state of knowledge in physics, including not only the phenomena but their interpretation as well, one does not have to be a real expert; in fact, with a few exceptions, an expert usually is a narrow specialist in a particular problem and is not even interested in a synthesis of all that is known. Yet, there is a certain minimum of technical knowledge of the phenomena involved and of the mathematical methods of analysis without which a general story or interpretation of the modern progress in physics is empty and meaningless. It is precisely this minimum of knowledge of the elements that the general reader usually lacks and is unwilling to acquire, making baby talk on the part of even such great writers as Eddington necessary and leaving the reader exactly where he was before, only more humble and discontented with himself and with popular writers.

Some years ago there was a tremendous rise in interest on the part of the general public in Einstein's theory of relativity, an interest which suddenly subsided with a feeling of disappointment and ennui. The man in the street, or at least those who tried to feed him on popularized relativity, learned three things, to wit.: (1) The very special phenomena which had led Einstein to his theory were in themselves not clear to an outsider, and frankly he was not particularly interested in them; (2) the mathematical side of relativity was entirely beyond him; (3) the principle of relativity of space and time did not modify or enlarge his cosmogony, metaphysics or religion; the new abstruse idea remained entirely disconnected from his intellectual and emotional life, and a few scraps taken in were promptly eliminated from his system, like indigestible portions of his meals.

In this article it is impossible even to touch upon the wonderful phenomena and unbelievably delicate measurements of modern physics; it is equally impossible to go into the specific problems of generalization and interpretation of these phenomena and the mathematical means so far mustered for the purpose. Therefore, this discussion must of necessity be couched in quite general terms borrowed, as much as possible, from the every-day experience of my readers.

Perhaps a simile will explain the fundamental nature of the problem with which the greatest physicists are at present concerned. Think of some isolated and fairly primitive agricultural and hunting community in which the political, social and economic relationships have been so well crystallized over a long period of time that no one can even conceive of the possibility of a different organization of society. Let us call this fictitious country Arcadia. Suppose now that because of the new and improved means of transportation and communication, the Arcadians have suddenly found themselves on the verge of quite active intercourse with one of the most civilized countries in the world, say the United States of America. The first ambassadors from Arcadia, upon their arrival in this country, would probably at once ask for the king and the chief priest, would look for large estates cultivated by slaves, vast hunting-grounds, and so forth. Then, after they will have understood the real structure of our society, it will gradually dawn upon them that the political relations at home, far from being universal and divinely ordained, are of very limited application. They will also find that the conditions in this country can not be described in terms of some equivalent institutions at home (even by overworking the adjective "heap-big") simply because there may be no native equivalents for trusts, filibuster, racket, etc. Ultimately, after much study of this country, some of the visiting statesmen may get a fair idea of the evolution of the modern state out of a primitive community, and in this manner mentally place the laws and customs at home in their proper relationship with the principal manifestations of political and economic life in America.

Similarly, a spectroscopist who measures what happens within the atom or an astronomer who deals with the most distant visible celestial objects soon finds that some of the phenomena observed can not be either checked, predicted, coordinated or explained in terms of the classical laws of physics and mechanics. Yet these classical laws, from the days of Galileo and Newton, have been found to be almost entirely adequate for "medium-size" objects, including our every-day life and the solar system. It seems, therefore, that the size of an object studied, or its distance, has something to do with the laws which it obeys; the expression "as immutable as Newton's laws of motion," while still somewhat effective as a figure of speech, can not be used in a strictly scientific treatise any more. Arcadian writers may still use in their essays the expression "as it is impossible to imagine a country without a king and a chief priest," but after their acquaintance with this country this expression at the most would become a weak figure of speech.

So far, no known phenomenon indicates a sudden change in the nature of the laws which it obeys when the size of the constituent parts is allowed to vary gradually. Consequently, we are forced to assume that the change from one set of physical laws to another is gradual. This is equivalent to saying that we really do not know yet the most general laws, but that these unknown laws, *within certain limits*, become almost identical with this or that law deduced

from a limited range of observation. So a sociologist may write a theory of structure of a modern industrial country, and another may write a theory of primitive hunting and agricultural communities, but to formulate one set of universal laws applicable to the whole human evolution (as was attempted by Spencer), from the ape-like state to Tammany Hall, is a stupendous task not yet successfully achieved.

If I use sand merely for ballast, in boxes or bags, the size of grain and the purity of the material are of no particular interest to me; in fact, I do not even think of individual grains and interstices. But if I use very minute quantities of sand, or mix it with cement, detailed properties of individual grains and impurities become of paramount importance. In the light of modern physics, classical scientists handled matter and energy like sand in big closed boxes the contents of which were unknown to them; the laws which they discovered were "bulk" laws; no wonder that these laws do not apply to small amounts of the contents of those boxes. On the other hand, our solar system is like a small grain of sand compared even to our own galaxy, not to speak of remote galaxies. So the time-space relationships deduced from a microscopic study of such a single grain need not necessarily hold true for the whole mountain from which the grain of sand was obtained. This is how Newton's laws of motion appear only as a first approximation in the theory of relativity.

A Greek philosopher taught that earth consisted of earth particles and water of water particles. I suppose many a passer-by went on his way rejoicing after having heard such a gem of wisdom, but I doubt if at the present time a naive theory of this kind would satisfy even a bright primary-grade pupil. The chemistry of a generation ago reduced all existing substances to atoms of some ninety-two elements and their combinations; modern physics has further reduced all these atoms to not more than three constituents, namely, portions of hydrogen and helium atoms, and electrons, in various combinations. The end of the subdivision is not nearly in sight, because each of these constituents has to be endowed with quite a complex structure of its own in order to account for some of the wonderful and manifold physical manifestations known. However, we have already penetrated well into the regions of such small distances that classical laws hold no more.

I can take a small piece of gold and keep on subdividing it by delicate instruments, always obtaining gold of the same density and of the same other physical and chemical properties. It does not make any difference whether gold is continuous or consists of discrete particles; it acts like a continuous solid. When, however, such thin sheets are reached that they become transparent to ordinary light and transmit electrons as through a sieve, one becomes vitally interested in the fine structure of the material. Mathematically speaking, it becomes necessary to assume a discontinuous structure. We now deal with phenomena in the interpretation of which one can not begin with the favorite classical phrase: "Imagine an infinitesimal parallelopiped of dimensions dx, dy, dz." It is like imagining such a parallelopiped in a crate of grapefruit. What you get depends on whether the dimensions of your parallelopiped are of the order of inches or of thousandths of an inch.

A similar situation exists with respect to energy, at least radiant energy. To a classical physicist, light and radiant heat were infinitely subdivisible, and rays could be imagined of any intensity,

down to zero. But for at least a quarter of a century, certain phenomena, such as black-body radiation and the photoelectric effect, defied an explanation, except on the basis of a coarse-grained structure of energy. The same assumption underlies modern spectroscopy and some other branches of physics. Thus was the so-called quantum theory of energy originated which is a counterpart of the atomic and electronic theory of matter. Here again the smallest element, or quantum, of energy (a photon) had to be endowed with various properties before an adequate explanation of even one particular group of phenomena has been reached, and the end of hair splitting is nowhere in sight.

The situation is further complicated by the fact that the minutest known particles of matter, electricity and radiation do not behave in distinctly different manner from each other on all occasions, but sometimes electrons behave like "wavicles," whereas quanta of radiation behave as if they were little chunks of something more material than ether waves. We may have yet to imagine an entity more general than either matter, electricity or radiation, of which entity these three are but particular manifestations. Twenty factory watches differ from one hundred similar watches in quantity only, and one watch differs from twenty watches in quantity only. But the elements of a watch, entirely taken apart, differ from a going watch in kind, and can not be described in terms of a going watch. So it seems as though modern physics has reached a stage of watches taken apart, and not only a new terminology but even a new point of view has become indispensable.

Man has an irresistible tendency to associate new things with old. When I meet a new acquaintance, I try to remember him by saying to myself that he looks somewhat like my Uncle John; islands and peninsulas have been named after familiar objects to which they have only a remote resemblance. Engineering terminology is full of expressions like wing nuts, choke coils, etc., borrowed from common life. Probably our Arcadians, after their return to their native country, would describe our president as a benevolent king, skyscrapers as big huts, and the censor of foreign books in the customs service as the chief priest sent from heaven. It will take them many years to change their point of view and to devise a terminology adequate to describe this country in independent terms. Similarly, modern physicists started at first to interpret intra-atomic phenomena in a macro-cosmo-morphic way. An atom emits waves of radiation, so that something must be jerking within it. The nearest approach to such a restlessly moving aggregate in the big world is the solar system. So the physicists evolved a central nucleus within the atom and a number of electrons revolving around it like planets. Difficulties arose with this interpretation, but they bravely struggled on, adding attribute upon attribute, and special "laws" galore, to make the theoretically predicted results check with experimental data, at least to the right order of magnitude.

Finally, the whole planetary structure of the atom became too complex for a mathematical treatment, or even as a picture, and the special "laws" appended to the picture were in a glaring contradiction with the big world of actual experience. The picture of the atom became a hybrid between some elements taken from the macrocosm and others tentatively added as working hypotheses. As soon as the faith in the possibility of constructing the microcosm entirely out of the elements of the macrocosm had been shaken, a few bold spirits undertook the task of wiping out

the whole clumsy structure and began to paint odd futuristic pictures of the atom, electron, quanta, chemical affinity and other fundamental concepts, without any reference to the big world. Evidently, such pictures by assumption can not contain cogwheels, connecting links, orbits and other crude elements borrowed from every-day experience. Therefore, the new theory in its first steps has become entirely mathematical. We must not talk of definite "things" within the atom, or even of definite physical attributes known only from observations in bulk. Instead we are offered a fundamental property of "something ultra-microscopic," expressed in the form of a new-fangled mathematical function, which, after being integrated over an appreciable quantity of matter or energy, gives results in fair accord with actual measurements. If this function can be successfully applied to a variety of problems, there must be something fundamentally sound in it; the function must therefore express something intrinsically extant in the atomic world, although we can not as yet express it in words, for to do this would be to go back to the picture theory of revolving spherical electrons, jelly-like ether and other childish concepts. The recent reaction in physics from the picture theory to the mathematical-function theory is not only natural, but unavoidable. No matter where man tries to interpret nature, he first assumes the simplest possible relationships from his point of view; an infinite resourcefulness of nature becomes clear to him much later. The earth is at first flat with the sun going around it; then the earth is grudgingly allowed to become spherical; still more grudgingly, ellipticity is admitted. Finally it is agreed that the shape of the earth is that of a geoid, which simply means that the earth looks like itself, has a shape of its own. The new tendency in physics is purely ideological; it is only because of the complexity of the abstract ideas involved that they are represented in the shorthand form of mathematical formulas and new mathematical operations. The great advantage is that later any story that seems plausible can be written, or a picture drawn, around these formulas and operations. Take a simple equation, $ax + b = c$, where x is an unknown quantity. This equation can be made to represent the story of a merchant who bought an unknown number of yards of cloth, of a train which started at an unknown instant from a station, of a man who pumped water at an unknown rate, and what not. In regions unknown a purely formal mathematical approach is the safest.

Another way out of being forced to describe too minutely a phenomenon about whose submicroscopic details and mechanism we know but little is to use the statistical method. I have no idea how long John Smith is going to live, but given sufficient data I could tell what his expectation of life or the probability of his dying within the next five years is, what the average income of men of his age and education is, etc. This information is not going to tell you when John Smith is going to die or what his income actually is, but somehow you will feel that you have obtained some useful and essential data about the man. The statistical method in physics was first applied to perfect gases, about the middle of the nineteenth century, giving rise to the so-called kinetic or dynamical theory of gases. With the statistical method, the mathematical physicist does not attempt to specify the position and the velocity of each of millions of particles of a gas, per cubic centimeter, but only computes the probability of a particle having a velocity or kinetic energy between some two given limits. With a

very large number of particles, this probability becomes identical with the actual number of particles endowed with that velocity or kinetic energy. For example, if the probability of being involved in an automobile accident in a large city, within a month, is one hundredth of a per cent., it simply means that actually one out of every ten thousand in that city figures in an automobile mishap each month.

The achievements of the classical kinetic theory of gases in checking and predicting phenomena quantitatively were so satisfactory that it was only natural to extend the statistical method to new problems, involving not only molecules of a gas, but quanta of radiation and electrons as well. However, the early results were far from satisfying, and a possible way out of the difficulty (not a complete solution as yet) has been found in the realization of the fact that there are different kinds of statistics, that is, different methods of computing a probability. We are gradually approaching the situation in statistical mechanics wherein statistical methods are becoming so flexible that almost any desired "bulk" law could be duplicated by choosing suitable assumptions as to single and compound probabilities of the elementary individual events. Let us hope that we shall not go in this respect as far as we have in politics and expert accountancy, where statistics are sometimes made subservient to the will to believe.

The differences between the probability computations in the old and the new statistics may be reduced to the following three: (*a*) In the classical theory, the amounts of kinetic energy ascribed to various particles varied continuously; in the quantum theory these amounts are assumed to vary in small but finite steps. (*b*) In the classical theory each molecule was supposed to have a distinct individuality, so that interchanging the positions or the velocities of two molecules gave a new distribution or arrangement. In the new statistical mechanics, the molecules, electrons or photons are assumed to be indistinguishable from one another, so that interchanging two elements does not give a new arrangement which would increase the total probability of that particular distribution. (*c*) In the classical theory of gases, the particles and their energies were assumed to be entirely independent of one another, whereas in the new statistics assumptions are made as to the maximum number of elements which can have a specified amount of energy each, so that different groups of particles are forced to occupy different "levels" of energy.

To obtain a general idea of the nature of statistical or probability problems in modern physics, consider the following simple case: There is a group of fifteen compartments or cells, corresponding to five units of energy, in the sense that any particle which is placed in one of these cells becomes thereby endowed with five units of energy. There is also a group of twenty cells corresponding to six units of energy. The total number of available particles to be placed in these cells is forty-five and the total combined energy of the particles is 250 units. What distribution of particles in the cells permits of a maximum number of individual arrangements, on the supposition that the cells are distinct whereas the particles are indistinguishable from one another? In actual problems on equilibrium of particles of gas, an assembly of electrons, or black-body radiation, the number of groups of cells, the number of cells per group and the number of available particles are very large, running into millions. Moreover, other conditions are imposed, for example: (*a*) the total number of photons is

not a constant given quantity as the number of particles is above; (*b*) not more than one particle may occupy a cell; (*c*) the presence of a particle in a cell increases or reduces its "attractiveness" for another particle by a given fraction. In this manner, one obtains the so-called Bose-Einstein and Fermi-Dirac statistics and their later modifications and generalizations.

The distribution which gives the largest number of individual distinguishable arrangements is the most probable distribution and the one about which the actual state of the aggregate fluctuates. Moreover, knowing the probability of various other arrangements, the average state of the aggregate (and consequently the magnitude of fluctuations) can also be determined. As stated above, the new statistical methods are quite flexible and can be modified and generalized as actual need arises. In a sense, they have an element of a picture theory in them, for example, as when it is stated that the presence of a photon in a cell increases the probability of another photon joining it in the same cell. However, the picture remains largely mathematical, without describing the shape of the hooks by means of which one photon attaches itself to another.

Now, even if we interpret all the subatomic entities in a mathematical form incapable of visualization, and even if we do the same with the vast spaces of the universe where our ordinary Euclidean relationships hold no more, this will not do away entirely with the bias of the medium-sized world in which we live. For, after all, even our mathematics has been entirely evolved in this inescapable workaday world of ours. To be strictly logical, we should not even use the addition and multiplication signs in the proposed formulas for the subatomic and ultra-galactic worlds, because these mathematical operations savor of the earthly occupations of barter, walking, measuring fields or counting slaves. But here we are almost reaching the limits of the workings of the human mind, *viz.*, the fundamental categories in which it can reason at all. Not that we have reached the highest concepts that the human mind is capable of; compare crude reasoning of a savage with that of our most advanced analytical scientists and synthetic philosophers. Yet, the progress in the very categories of thinking must of necessity be slow and only possible at large intervals, when a new genius arises among us. The purely formal or experimental progress in science is continuous so long as there are talented and devoted men working on a given problem.

Summarizing, I would express my opinion upon the changing point of view in physics as follows: (1) Within the last thirty years a very rapid progress in the technique of measurements has extended the data of physics to extremely small quantities and the data of astronomy to enormous distances and unimaginably large intervals of time. Moreover, many of these data are correct to a high degree of accuracy. (2) The human mind is never satisfied with a mere accumulation of data and always wants to interpret them in terms of some general laws or relationships. The first and natural step was to extend and to adapt the previously known laws of geometry, physics and astronomy to the newly conquered regions. (3) Since these laws failed in some cases, especially in the intra-atomic world, a picture theory of the microcosm was evolved, patterned somewhat after the solar system. Later it became necessary to add numerous details and special laws to the initially simple picture, and even then it did not agree with many experimental data. (4) As a reaction, the picture theory of the atom has given

place to a mathematical or ideational theory (wave mechanics) in which the unknown inner workings are expressed by newly devised formulas and operations for which no physical picture is offered. The proof of these formulas lies in the results obtained by applying them to measurable quantities of matter or energy. (5) In astronomy, the picture theory step was omitted and the generalized theory of relativity has given us directly new time-space relationships, impossible to be visualized, and strictly mathematical in their formulation and application.

I shall not attempt a prophecy as to whether physics will continue to progress and develop at the present unprecedented rate, or whether the progress will slow down. Even assuming that no additional new ideas of importance are to be evolved by the present-day physicists of the first rank and no new scientist of extraordinary vision and skill is to appear say within the next twenty years, it is difficult to conceive of an appreciable slowing down of research in physics. The brilliant and revolutionary ideas hurled at us within the last ten or fifteen years will be sufficient to keep hundreds of talented workers busy for many years to come applying and further developing them in detail. We should be grateful for what has been so generously revealed to us and see to it that the new knowledge has been put to proper use for the benefit of humanity before expecting more.

PENSIONS FOR SUPERANNUATED EMPLOYEES

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Superannuated employees both in public employment and in private industry are presenting a problem of considerable interest and importance. My first interest in the problem began about twenty years ago through some actuarial inquiries. This interest was extended through my duties as the actuarial member of the Illinois Pension Laws Commission from 1915 to 1919. Since that time many opportunities have come to me to observe the development and reorganization of pension plans for various groups of employees. As the actuarial adviser of the Chicago Pension Commission in 1926, special opportunities came to me again to study the progress in pension plans for public employees. With these rather interesting experiences as a background, it seems not inappropriate to comment on recent developments and to venture in some respects to forecast the future development of pension plans for groups of persons in a common employment. While my main interest has been on the actuarial and technical phases of the operation of pension systems, I shall have the temerity to deal to a considerable extent with the economic and social aspects of the problem.

It is a simple historical fact that the problem of superannuated employees arose much earlier in the public service than in private industry. In fact, some Continental European countries have had pension plans in force for government employees for more than one hundred and fifty years. England has paid civil service pensions since 1810. The earlier development of pension plans in the public service than in industry seems very natural when we recall that, previous to the present age of large machinery, the representative man in industry usually would own his own business or at least the tools with which he earned his income. The units for business operations were small. Relatively more people owned their own homes than at present. Likewise, relatively more people produced part of their own food and clothing than at present. With the development of industries operating large units, vast numbers of employees are very dependent on current income from employment just as public employees are and were at an even earlier date than employees in industry.

To simplify and clarify my terminology, let me say that, throughout this paper, the expression "public employee" will be used in a broad sense to denote civil service employees, teachers, ministers of the church and such other employees in the educational, religious or governmental service as hold positions with a tenure of office with a degree of permanency not less than that of urban public school teachers. The consequences of abruptly stopping the employee's income under present conditions is likely to involve serious hardship both on the employee and his dependents. It is fairly obvious that the continuance of income even for the most substantial class of employees is ordinarily exposed to four major hazards: Unemployment due to business depression; disability due to sickness or accident; death, leaving dependents; old age dependence.

With respect to the first of these hazards—unemployment—we may say that to avoid part of the distress due to unemployment various preventive measures

are employed. In some countries, there are at present formal provisions of law to relieve such distress. For example, we may cite the National Insurance Act of 1911 of Great Britain and the Canadian Federal Provincial Old Age Pension Act of 1927. With respect to disability due to accident and sickness, we note with interest the progress of group health insurance. With respect to the hazard of death, life insurance in its various forms, including group insurance, is daily becoming more effective in the relief of distress. There remains for our consideration the hazard of old age dependency. Various views are held as to the remedies for old age dependency among employees.

It is simply a fact that a large percentage of employees do not make proper provision for old age. Whether it is reasonably practicable for them to provide for old age by the ordinary methods of thrift and saving under present economic and social conditions seems to be a debatable question. On the one hand, we find those who would put the obligation to save for old age entirely on the individual. On the other hand, we find serious students of the subject who do not think that wage-earners in industry, under existing conditions, can be expected to provide for old age. Similar views are frequently expressed in reference to public employees. In brief, we find at one extreme the man who believes in perpetuating the old order by placing the responsibility entirely on the individual for preventing his own old age dependency. At the other extreme, we find the man who would adopt a scheme of general old age pensions to insure the people against old age dependency. But the adoption of general old age pensions presents so many thorny questions that it looks as if the wise course is to seek the solution of the pension problem in the relationship of employer and employee rather than to adopt a scheme of general old age pensions. That is to say, it seems likely that there is a middle ground somewhere between the two extreme positions which offers the best solution of the problem of superannuation of employees both in industry and in the public service. The golden mean is probably to be found in the cooperation of employer and employee to solve the problem in a businesslike manner. Such a point of view would seem to benefit both the employer and the employee. At least in theory—and it is believed that the theory is fairly well realized in practice—pensions for superannuated employees are beneficial to the employer. Among several possible benefits, such as continuity in service and improvement in the spirit of the organization, the main benefit of the pension system is to protect the public service and business from incompetence through the continuance in the service of employees after their periods of efficiency are passed. This point was well brought out in an editorial in *World's Work* of February, 1923:

> Most large employers of labor find a system of pensions essential to the efficiency of their staffs. One of their greatest problems has been the disposition of employees who have outlived their economic usefulness. Even the most mechanical practitioner of "efficiency" recognizes that humanity and gratitude are imponderables that can not be disregarded. The result was that useless workmen and executives were kept at work; not only was their labor a liability, but their presence prevented the promotion of effective men. In this way the pension system became an economic necessity. The time is probably not far distant when every prosperous employer of labor will have adopted some plan providing for the future of its workers. Properly regarded, it is not philanthropy; it is simply business.

The view that sound business practice will lead to the adoption of scientific pension plans in the future is strongly supported by the following statement from Reinard A. Hohaus,[1] assistant

[1] "The Function and Future of Industrial Retirement Plans."

actuary of the Metropolitan Life Insurance Company:

> It is advantageous that the employer regard the problem as a business one, and not as one of altruism, charity or reward. When the employer realizes that he must pay pensions, his business training impels him to find a plan which will, in addition, secure as many by-products as it can, such as reduction in turnover, improvement in morale, etc. He will seek a plan which is systematic and definite and sound, and which assesses the cost to the time and place in which it was incurred.

Turning next to the benefits to the employee, the most direct benefit of a pension system to an employee is that it means the prospect of a life annuity beginning at the end of the period of efficient service in the employment. If the annuity is sure to be received, this means protection against the hazard of old age dependency. A well-constructed pension system may, however, bring some benefits that are not quite so direct. Certain types of contributory pension systems seem to me to be significant factors in the promotion of thrift.

Grant, then, that a well-designed pension system is a benefit to both employer and employee, it naturally follows that the pension problem should be studied by both employer and employee with a view to the inauguration of sound plans that are adapted to both the immediate and future needs of the organization and its employees.

Such studies have been made within the past fifteen years of pension systems for public employees by various state and city pension commissions and by some other agencies. For example, extensive studies of the subject have been made and published in reports by the Commission on Pensions of Massachusetts (1914), by the Commission on Pensions of New York City (1916–19), by the Illinois Pension Laws Commissions (1915–19) and by the Carnegie Foundation for the Advancement of Teaching. Many of the principles and provisions of sound pension plans developed in these reports have been summarized and discussed in a book by Lewis Meriam on "Principles Governing the Retirement of Public Employees" and in one by Paul Studensky on "Teachers' Pension Systems in the United States," both published under the auspices of the Institute for Government Research. It was easy to establish the fact that there are in operation many pension systems for public employees that make promises of pensions with little regard to the financial obligations involved in the promises. The difficult task is to find the remedy for such unfortunate practices. The great majority of the pension systems for public employees are either of the "cash disbursement" type or of a type sometimes called the "pot" type. Under a cash disbursement type, the pensions are paid out of the current revenue from the same sources that provide current wages and salaries. By a "pot" type is meant a plan under which somewhat more revenue is collected from employees and employer than is needed currently to pay pensions in the very early years of operation. The money is kept in a so-called "pot" without any definite actuarial knowledge as to the sufficiency or insufficiency of the amount in the "pot" together with future revenue to carry out the promises of retirement allowances. In short, the employee who is depending on such a system to provide a pension in old age is not unlikely to find very little in the "pot" in that future period when his pension rights mature.

Just a little more than ten years have passed since the writer published a paper on "Recent Developments in Pension Plans for Public Employees" in the *Record* of the American Institute of Actuaries. It was there pointed out that we had witnessed in the five preceding years the adoption of reserve pension systems built on comparatively sound financial bases for state employees and teachers in Massachusetts, for

teachers in New York, Pennsylvania, Vermont and Connecticut. These plans followed closely the recommendations of various pension commissions and other agencies that were studying the pension problem. In the ten years since the publication of that paper the drift toward financially sound plans has continued, and much progress has been made in the further study and adoption of such plans. For example, in the State of Illinois alone, we find five reserve pension systems with more than 20,000 public employees participating in partially contributory plans. We find New Jersey, Ohio and Wisconsin added to the list of states with state-wide reserve pension systems for teachers. Several states, including Virginia, Michigan, Iowa and North Dakota, have well-designed plans under consideration for state-wide systems for teachers. We find reserve systems adopted for various groups of civil service employees. Among these is the system for United States classified civil service employees.

Among the recent studies and reports, special mention should be made of the report of the committee of one hundred on retirement allowances of the National Education Association published in 1926. This excellent report makes it fairly obvious that our leaders in the fields of elementary and secondary public school education are interested in sound pension legislation of the adequate reserve type. The report gives also in very clear form the prevailing opinion with respect to controversial points.

Turning next to the industrial field, we note that the industrial pension systems have been studied in recent years by various agencies, and there is good evidence that some employers are vitally interested in the study of this problem. In 1922, a book entitled "A Critical Review of Industrial Pension Systems" was published by Luther Conant, Jr. In an appendix to this book there is presented a brief outline of the provisions of each of the pension systems of ninety-six industrial establishments. The book presents, as implied in the title, an analysis of the significant characteristics and underlying principles of sound pension plans for industrial employees. In 1925, the National Industrial Conference Board published an analysis of 248 different retirement systems operated by 245 different establishments. More recently the Industrial Relations Counselors, Incorporated, have been conducting an investigation of company pension plans in the United States and Canada. A summary of some of the results of this investigation, published in *American Labor Legislation Review* for March, 1929, by Murray W. Latimer, indicates that 466 pension systems have been found in operation, of which 338 are of a formal type while 128 are of an informal character. These 466 systems examined by the Industrial Relations Counselors, Incorporated, were operated by companies employing in the neighborhood of four million workers.

The great majority of the industrial pension systems now in operation are of the cash disbursement type. The employer pays the pension out of current operating expense, making no provision for meeting future obligations. This method has the advantage of simplicity, but it does not stand critical analysis. The pension is based on the tacit assumption that it is a gratuity, and, in the case of some systems, the employer may modify or discontinue the plan at his discretion. As a result of studying various plans in the future as a business problem, it is my prediction that the drift will be away from the cash disbursement plan towards a fundamentally different type of plan. The cash disbursement systems will be replaced for good cause. The "pot" plans will be replaced for equally good, and perhaps for still better reasons. What,

then, will be the essential characteristics of the pension systems of the future for both public and industrial employees?

There is some danger of clouding the issue by bringing into the picture several factors besides old age inefficiency that are very naturally suggested as welfare measures that might be added as sort of riders to the pension plan. This remark is not meant as a criticism of plans that have certain riders. The riders may involve widows' benefits, children's benefits, sickness and accident benefits, and may serve a useful purpose. But my purpose in the present discussion is to exclude all factors except those which pertain to the problem of old age inefficiency in the future of any employment. With this limitation, it seems that the following will be the chief features of future pension plans.

(1) At the date an employee enters upon his pension a sum actuarially equivalent to the benefit will be on deposit in an organization practically as permanent as a legal reserve life insurance company. Such deposits will ordinarily be made possible by the accumulation of deposits over a period of years as nearly concurrent as practicable with the accrual of the liability to pay the pension.

(2) The employee will have a legal claim to the pension, subject to his meeting the prescribed conditions, such as requirements pertaining to age, service and contributions.

(3) The amount of the pension will be fixed with due regard to the variations in standards and habits of life which exist among employees of different earnings, and with due regard to length of service.

(4) The retirement annuity will be granted only on the attainment of an age at which the period of efficiency is very likely to be passing, and retirement will be compulsory after a certain later age, say seventy, except by special action initiated by the employer with the approval of the employee.

(5) The equity of the employee in his pension expectations will be recognized when he withdraws from the employment to the extent to which his salary has been reduced because of the pension prospect.

(6) The operation of the pension system will be under the effective supervision of the State Insurance Department.

With the forecast of the essential features of the future pension plans thus stated somewhat dogmatically, some discussion seems appropriate. The first essential feature relates to the scheme of financing the future plans on a reserve basis. It is predicted that they will be financed on the fundamental principle that at the date of retirement the actuarial equivalent of the benefit will be deposited on behalf of the retiring employee in a fund administered by an organization whose permanency is substantially equivalent to that of a legal reserve life insurance company. To make the operations under this fundamental principle practicable and effective, it will ordinarily be desirable for the employer and employee to deposit in the pension fund currently, during a considerable number of years prior to retirement, equal amounts or amounts that bear a prescribed ratio to each other. These deposits or contributions which the employee makes through deductions from salary and which the employer makes through an addition to compensation will be accumulated at compound interest.

While I thus believe the drift in future pension plans will be in the direction of plans involving joint contributions by employer and employee over a long period of employment, it seems not unlikely in some cases that the period of making contributions should not cover the whole period of employ-

ment and that there may even be cases in which the practical advantages of a non-contributory system outweigh the theoretical advantages of the contributory system, but in every case that has come to my attention it is essential that the plans be so constructed that the actuarial equivalent of the benefit be on hand at the date of retirement. To illustrate from a concrete case, the writer recently examined the operation of the pension system of a large oil company in which the labor turnover during the past ten years was so large that it would almost surely be impracticable to make the scheme contributory for all employees. If it were made contributory for all employees without refunds of contributions upon withdrawal from the employment injustice would be done. On the other hand, if the contributions were refunded upon withdrawal, the administrative expense would probably be so large as to interfere seriously with the practicability of the plan. In such a case, it seems more reasonable for the company to build the proper reserve at retirement on behalf of each employee who is within such a number of years, say fifteen years, of fulfilling the requirements for a pension, that he is not very likely to withdraw from the employment, rather than to subject the operations of the plan to the administrative expense of a contributory system over a long period of time on employees most of whom will withdraw from the employment. Possibly such a system in cases of large turnover may be made contributory over the shorter period, such as the fifteen years preceding retirement age during which the reserve is being deposited, but in this relatively short period the employee would probably be able to contribute only a small per cent. of the total sum required to provide a pension of the desired amount. It seems that the least inference to be drawn from this discussion is that the reserve at retirement age should be built up gradually, in as practical a manner as possible, as the pension rights accrue. On the question of the reserve system, Hohaus, in the paper already cited, expressed the matter aptly in the following form:

> Sound business practice has made it almost mandatory to charge off depreciation for buildings, equipment and other capital assets while in active use and to build up a sinking fund for their replacement. This practice simply provides the funds for the replacement liabilities as they accrue, and not as they mature. This method was not always in effect, but required considerable time, patience and educational work to accomplish its adoption. In like manner, the soundness of a similar practice for the replacement of the superannuated is becoming more generally admitted and, in time, will be in general use. Moreover, I believe that as this reserve principle is recognized, employers will insist on plans, the benefit of which are such that liabilities for them may be definitely determined and so not depend upon the course of such changeable rates as salaries and withdrawals, as those of many present plans do.

The second essential feature stated above is that the employee who has satisfied the requirements for a pension should have a contractual right to the benefit promised. This feature clearly involves an important principle. It seems fairly obvious that the non-contributory pension systems of the "discretionary" type are very far from granting a contractual right. In fact, they very commonly deny explicitly that any such right exists. Some of them state that the plan may be modified or discontinued at the discretion of the employer. There is a reason for this kind of provision. The employers have been feeling their way, and it is rather unreasonable to expect them to guarantee the unsound pension systems which in many cases have probably been copied without careful study. If such a non-contributory system is so well established that employees attach a value to the benefit as part of compensation, it has been fairly well established that, in the large, current compensation will be at a lower level than it would be if the pension system did not exist. In such a situa-

tion the employee clearly has a moral right and should have a contractual right to a pension. When business men study the pension problem more carefully there will be a drift towards making the payments sure. I think it is betraying no confidence for me to say that in the meetings of the Illinois Pension Laws Commission of which Rufus C. Dawes was the member versed in financial affairs, he frequently made remarks to the effect that it was the sureness of the pension rather than its exact amount that seems of first-rate importance and that the pension payments should be made as nearly contractual as possible. Moreover, my experience leads me to say that there exists considerable evidence that employers are as much interested in making payments of pensions contractual as are the employees.

With respect to the proper amount of the pension, it seems fairly obvious that the pension should be of sufficient amount to provide in a reasonable manner for the necessary wants of the beneficiary after the age of efficiency is passed. This amount varies, however, in accord with the standards and habits of life previously followed. If the benefit is too small, there will be a tendency to retain the employee in the active service after his period of efficiency is passed. The salary or wages paid to such an employee is, in a sense, the most expensive kind of a pension. While the amount of pension and salary should be correlated, it seems far from ideal to have the amount based on final salary. In what the writer regards as the ideal scheme of financing a plan, the amount of pension is based on the accumulations from a certain per cent. of salary, set aside throughout a considerable period of service. In the ideal scheme the amount of the pension is simply the actuarial equivalent of such accumulations to the age of retirement.

With respect to age and service requirements for a pension, let me say that some pension systems of the financially unsound variety prescribe merely a period of service such as twenty or twenty-five years as a requirement for a pension. There are others that prescribe both a period of service and a minimum age of retirement. The situation with respect to age and service requirements of different systems is well stated in the 1916 report of the Illinois Pension Laws Commission. That statement portrays an almost haphazard set of provisions which exist in regard to age and service requirements even when the nature of the employment is the same. It seems fairly obvious that some of the greatest abuses of pension systems have their source in the failure to specify a proper age of retirement. When the only requirement is twenty or twenty-five years of service, and the pension consists of a fair per cent. of salary, say in the neighborhood of 50 per cent. of final salary, a considerable number of men enter on pension at ages under fifty. These men are apt to be the most capable men in the employment, as such men may accept the pension and obtain employment elsewhere to advantage. It is entirely foreign to the objects of a sound pension system to enable men to retire on pensions in the prime of life. On the other hand, a standard compulsory age of retirement that insures retirement when it is practically certain that the average employee has passed his period of efficient service is essential. However, instead of a hard and fast compulsory retirement rule, there should be left open the possibility of retaining the employee in the active service by special administrative action initiated by the employer with the approval of the employee. To apply the principle that a pension system is to make practicable and effective the retirement of the employee when his period of efficiency has probably passed and to require his retirement when it is very sure that this period is passed should be the primary objects in the administration of a pension system.

Our next essential feature relates to withdrawal benefits. It seems fairly obvious that when an employee who has contributed to a pension fund is separated from the employment by resignation, dismissal or death an equity must be recognized. In the case of a contributory plan, there is hardly any question that at least the deposits created by deductions from salary should be refunded. The debatable point is on the question as to whether more than these deposits should be refunded.

So far as the writer has been able to learn, all non-contributory pension plans involve the loss of pension right upon withdrawal from employment without regard to length of service. The question as to whether this procedure is equitable is tied up with the question of the effect of a non-contributory pension system on the general level of wages and salaries. But the view has been fairly well demonstrated[2] that in case, and only in case, a non-contributory pension system has become so well established that the employees regard the prospective pension as definitely assured, the operation of the system of pensions tends to develop a scale of wages and salaries on a somewhat lower level than would prevail in the absence of the pension plan. If this view is correct, the withdrawing employee under certain circumstances does not receive equitable treatment. This was the contention of the civil service employees of England in the agitation which preceded the modification of their pension plans in 1909.

The last essential feature on my list relates to supervision of the operations of pension systems by state departments of insurance. It seems clear, in considering the operations of a pension plan, that both the employer and the participating employee should have the benefit of general supervision and of effective examinations from time to time by the state insurance department. In fact, all the arguments for state supervision of life insurance companies may be applied with equal force to the organizations operating pension funds. The proposed contractual provisions will be of real worth in industrial pensions only when the system is in charge of an organization which will not, because of the failure of the business in which the employee gave long-continued active service, find itself unable to pay pension obligations that have accrued. We have already had some examples of hardship to annuitants of pension systems because of the failure of the business in which the annuitants gave their active service and on whose solvency the annuitants were dependent. A few more such failures will lead to regulatory legislation which in turn will involve state supervision.

Before bringing to a conclusion this discussion of my forecast of the main characteristics of the future pension plans for groups of employees, let me sound a note of warning against the inference that I am predicting that the majority of the pension plans of the United States will have these characteristics in the near future. My prediction is far from this. The progress will probably be slow but rather sure. It usually takes considerable time to educate both an employer and his employees to recognize that a sound and equitable pension plan will be economical, in the long run, in spite of the substantial current contributions to the fund. Moreover, it is likely to take considerable time in any given organization to make the necessary gradual transition to plans with the proposed characteristics. However, when American business men really study this problem carefully, the drift towards pension plans of the adequate reserve, contractual type will almost surely be assured and the movement towards plans whose characteristics we have briefly discussed may be more rapid than might be anticipated.

[2] Conant, "A Critical Analysis of Industrial Pension Plans," p. 97.

IS THE PRESENT AMERICAN IMMIGRATION POLICY SOUND?

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WHAT Lothrop Stoddard has called "a master stroke of constructive legislation" became effective in the United States July 1. Stoddard referred to the national origins plan of immigration restriction which fixes at 153,714 the annual number of immigrants who may enter the United States and provides that 43 per cent. of these must come from Great Britain and North Ireland.

In this essay I propose to answer four questions: What should immigration restriction seek to accomplish? Have previous immigration laws been satisfactory? Is the national origins immigration law "a master stroke" in immigration legislation? What shall America do with respect to immigration?

I

Immigration restriction has two aims: (*a*) to admit during a given period of time no more immigrants than a country can absorb without impairing the economic position of that country's resident population; (*b*) to admit only those racial, national and occupational groups which can be assimilated biologically, socially and economically.

The number of immigrants who can safely be admitted into a country within a year or period of years depends upon the existing relationship between land and natural resources and the number of persons residing in that country.

Obviously it is desirable to attain, in so far as possible, the most productive ratio between population and resources. This ratio will have been attained when, in return for whatever expenditure of effort the people of a country regard as normal and proper, they obtain the largest, permanently practicable per capita product. Professor A. B. Wolfe has called this ratio the *optimum*, and a population of this most efficient size, the *optimum population*. An optimum population would, provided there existed an equitable system of distribution, be characterized by the highest possible standard of living.

Neither a large nor a small population, therefore, is *per se* desirable in any country. So long as an increase in population will increase the per capita product such an increase in population is desirable. So soon as a further increase in population threatens to reduce the per capita product no further increase in population should be permitted. Otherwise the standard of living is bound to fall.

It is absurd to argue that it can not definitely be determined when an optimum population has been reached. True, what constitutes an optimum population changes from time to time because the technique of production and the international economic position of a country change. True, assuming that one can determine what is the optimum population, a government lacks the means of so controlling births and deaths as to achieve this optimum. Nevertheless, it is much preferable to make the optimum population the ideal rather than to cry blindly for either a larger or a smaller population. Indexes of production enable man to determine when the optimum population has been reached in a country. Skilfully disseminated propaganda may tend to increase or decrease that country's birth-rate; the volume of immigration can be completely regulated.

Once the optimum population has been determined for a country it is necessary to measure the trend in natural increase (excess of births over deaths), for only then can it be known whether the population is breeding up to or beyond the optimum. If the births in a country are so far in excess of the deaths that the optimum will soon be reached or exceeded, no immigration should be permitted. If, however, a country's population gives no promise of soon reaching the optimum through natural increase then immigration is desirable. Present-day Great Britain illustrates the former and present-day Argentina the latter case.

II

Having determined the number of immigrants that are needed in a country it is next necessary to select those races, nationalities and occupational groups which are desirable.

A country should admit as immigrants only those racial and subracial stocks which amalgamate satisfactorily with the native population. Satisfactory amalgamation through intermarriage will take place only provided that the spread is not too great between the native and the immigrant racial stocks, and that the native population is willing to intermarry with the immigrant stock.

Clark Wissler, curator of the American Museum of Natural History, summarizes prevalent authentic doctrine on racial intermixture in these words:

> While we have little positive knowledge of what happens when races mix, there are not wanting hints that the result is frequently an illy balanced biological individual. Thus Negro-White, Polynesian-White, Australian-White, etc., are combinations of what are sometimes regarded as disparate anatomical units. Some observations in schools and in the army suggest that such mixtures often result in lowering of mentality. However, satisfactory data on these subjects are not available because the subject has not been sufficiently studied in a scientific manner. So, while the subject has not been more than scratched and there are abroad in the land men shouting vociferously that race counts not at all, that peoples should mix indiscriminately, while others say that mixture always results in undesirables, neither of these views can be regarded as unprejudiced or undogmatic, since there are suggestions here and there that the results of such intermixture are not making for progress. . . . The chaotic state of public opinion on this subject is largely due to the lack of reliable scientific data.

If Wissler's statement is accepted as substantially correct, no white country can afford to admit either brown or black immigrants. This is not to imply that either the black or the brown races are inferior to the whites; it is only to state that neither white-black nor white-brown hybrids are stable and desirable biological types. It is possible but improbable, also, that Chinese and Japanese immigrants ought to be excluded from white countries on racial grounds.

If Wissler's statement is held to be invalid, brown, black and yellow immigrants ought, nevertheless, to be excluded from white countries, for in practically every white country the racial prejudice against brown, black and yellow men is so great that their intermarriage with the white population is practically tabu. Hence, even if desirable biologically their amalgamation with the whites through intermarrige is not permitted to take place. It is possible, however, that in the future existing prejudices against the yellow, brown and black races will disappear in proportion as these races achieve complete national sovereignty. Then, if biologically acceptable, yellow, brown and black men will be received in all countries desiring immigrants.

Whether or not yellow-white intermixtures prove desirable may be cleared up in the near future by a study of yellow-white intermixture in Manchuria, for in parts of that state thousands of marriages have taken place between Chinese and Russian whites, exiled from Russia because of czaristic sympathies.

No white country ought, on racial grounds, to reject white immigrants from any other white country. In the

veins of every white nationality flows the blood of all three white races, Nordic, Alpine and Mediterranean. In no country do we find a people that is pure Nordic or pure Alpine or pure Mediterranean. All white nationalities, whether British, French, German, Italian, American or what not, are composites of all three white races. Hence no white country can logically, on racial grounds, exclude whites of other nationalities. The only proviso that should be made is this: admit only those whites whose physical and mental make-up is as good as, or better than, the average of those living in the immigrant-receiving country.

Countries which receive immigrants should determine carefully what economic classes of immigrants they need. Ostensibly only those should be admitted who can perform occupational tasks for which there is a need. Thus if a country has too many miners and too few farmers it should admit not miners but only persons adapted to farm life. If there exists a dearth of unskilled workers and an excess of skilled workers only those should be admitted who can do unskilled work.

In order that only those immigrants will be admitted who are physically and mentally equal or superior to the average native population comprehensive physical and psychological tests must be administered. Those morally undesirable, such as criminals, other than political, ought not to be admitted, even though they pass other tests.

Social assimilation of immigrants must be fostered if they are to intermarry and amalgamate with the native population. To foster assimilation and amalgamation state, church, school and philanthropic institutions must cooperate.

In summary a sound immigration policy demands that: (1) Only as many immigrants be admitted as is consonant with a statistically determined optimum population; (2) members of races which for any reason are prevented from amalgamating with the resident population should be excluded; (3) only those capable of performing the occupational tasks for which there is a need should be admitted; (4) physical, mental and moral fitness should also be criteria for admission, and rigid tests should be given to determine such fitness; (5) organized effort should be made to foster the racial assimilation of the immigrant.

III

Until the passage of the immigration law of 1924 no federal statute for the regulation of immigration even approximated the requirements listed above. Not until 1876 did the Supreme Court declare that Congress had the power to regulate immigration. In 1882 the first general immigration law and the Chinese Exclusion Act were enacted. The former provided that lunatics, idiots and persons likely to become public charges were to be excluded; an earlier law had excluded prostitutes and alien convicts. Other classes of undesirables were added to the debarred list under acts passed between 1882 and 1917. In 1917 Congress passed a bill providing for a literacy test designed to limit the number of immigrants, but few were excluded, as any moron could pass the test. In 1920 an act approved in 1918 was amended "to exclude and expel from the United States aliens who are members of the anarchistic and similar classes."

In 1921 an emergency measure was passed to stem the influx of millions of Europeans who wished to escape the misery and burdens they inherited from the war. Agitation for the restriction of immigration had been steadily increasing in volume since the disappearance of the frontier in the closing decade of the nineteenth century. The growing labor movement feared a wage decline. Racial purists feared the mongrelization of the American stock, for after 1890 more than one half of the immigrants came from eastern, central

and southeastern Europe and hence differed markedly from the native Americans in racial composition and cultural background. Nationalists, become vocal during the World War, feared for our national solidarity and homogeneity. Consequently when 805,228 immigrants came in 1921 and it was threatened that two millions would come each year despite the literacy test and other frail barriers, a law was passed in 1921 providing that "the number of aliens of any nationality who may be admitted under the immigration laws of the United States in any fiscal year shall be limited to 3 per centum of the number of foreign-born persons of such nationality resident in the United States as determined by the United States census of 1910."

The total admissible under this act was 357,803. Of these 55.2 per cent. were assigned to northwestern Europe; 43.7 per cent. to southern and eastern Europe, and 1.1 per cent. to designated parts of Asia, Africa and Australia. No limit was placed upon the number who might come from North America.

The act of 1921 proved satisfactory in but one respect: it prevented the heavy influx of immigrants who would otherwise have entered the United States. The objections raised were numerous. Principally it was contended that the quotas fixed for the countries of southern and eastern Europe were too large when compared with the number these countries had contributed in the past to make up the American population. That is, English, Dutch, Germans, Scandinavians, Irish and Scotch-Irish had made up practically the entire immigration prior to 1890. Consequently, since the blood of these peoples bulked large in the American stock, it seemed advisable that the majority of immigrants admitted under any quota plan should consist of the peoples mentioned. For these peoples resembled the American stock not only in racial make-up but also in political ideals, social training and economic background. The immigrants from southern and eastern Europe, on the contrary, it was asserted, had different political, social and economic backgrounds and hence could not well be assimilated; further, as they were predominantly Alpine or Mediterranean in racial make-up they could not be satisfactorily amalgamated with the native American population. Finally, it was charged, the southern and eastern European immigrants were poorly educated, had too high a birth-rate, consisted of inferior biological stock, were not amenable to Americanization and therefore threatened to stifle progress by making our population too heterogeneous. The army and other intelligence tests and divers evidence of questionable nature were used to bolster these arguments.

Cognizance of the above arguments was taken in the act of 1924 which provided that "the annual quota of any nationality shall be 2 per centum of the number of foreign-born individuals of such nationality resident in continental United States as determined by the United States census of 1890, but the minimum quota of any nationality shall be 100." The total annual quota was fixed at 164,667, of whom 84.5 per cent. consisted of northwest European stock. The act of 1924 provided further that this quota plan would stand until July 1, 1927, after which date quotas would be based upon national origins.

Neither the act of 1921 nor the act of 1924 can be said to have effected a sound immigration policy. The objections to each of these acts are the same as the non-statistical objections to the national origins plan and will be considered in that connection.

IV

Under the national origins plan the annual quota of immigrants for any

nationality "shall be a number which bears the same ratio to 150,000 as the number of inhabitants in continental United States in 1920 having that national origin bears to the number of inhabitants in continental United States in 1920, but the minimum quota of any nationality shall be 100." In plain language this means, for example, that since in 1920 there were in the United States 89,506,558 persons born in, or descended from persons born in, quota countries and since 39,216,333 or 43.814 per cent. of these were of British or North Irish origin Great Britain and North Ireland may send $.43814 \times 150{,}000 = 65{,}721$ immigrants to the United States each year.

The total number admitted each year is fixed at 153,714 for the quota countries. Of this number 82.7 per cent. are assigned to Great Britain, Ireland, France, Germany, Scandinavia, Switzerland, Austria and Belgium. Practically all the others come from southeastern Europe. No limit is placed upon immigrants from countries in North America.

The objections, statistical and non-statistical, to the national origins plan will be considered in order.

It is statistically impossible to determine that 39,216,333 of the white residents in the United States in 1920 were of British and North Irish extraction. This figure consists of four elements: (*a*) 31,803,000 descendants of the people of British and North Irish origin enumerated in the first census taken in 1790; (*b*) 3,728,700 grandchildren, great-grandchildren, etc., of British and North Irish immigrants who arrived after 1790; (*c*) 2,308,419 children of immigrants from Great Britain and North Ireland, and (*d*) 1,365,314 immigrants born in Great Britain and North Ireland.

Of these four elements only (*c*) and (*d*) are given in the census of 1920. Even then for some countries it is impossible to calculate element (*c*). For example, in the census of 1920 children of parents born in prewar Austria-Hungary gave Austria-Hungary as the birth-place of their parents. To-day Austria-Hungary is broken up into many different parts. How, then, other than arbitrarily, can it be said that so many children of parents born in Austria-Hungary are Czechoslovakian, so many Austrian, so many Hungarian, etc. Not even the use of the reported mother tongues removes this arbitrariness.

The estimate of element (*a*) proves to be a sheer conjecture. It is estimated that in 1920 the descendants of the 3,172,444 whites enumerated in 1790 numbered 41,288,570. This was computed as follows. The census of 1920 showed that of the native whites up to five years in age, 75 per cent. had native parents. It was assumed that the parents of these children were aged thirty to thirty-five in 1920, grandparents sixty to sixty-five, and so on. Now of the natives aged thirty to thirty-five, 76 per cent. had native parents; of those aged sixty to sixty-five, 77 per cent. had native parents. Hence of the native children up to five years of age in 1920, 44 (75 x 76 x 77) per cent. had native grandparents.

So far, so good. But when one tries to determine how many native Americans had native great and great-great-grandparents one engages in guesswork because the necessary data are lacking. The census of 1890 gives the nativity of parentage of natives aged eighty years or more. These were born prior to 1810 and ought, therefore, it is assumed, to enable one to gauge what part of the population born between 1790 and 1810 had native parents. But too few persons survived in 1890 of those born before 1810; in 1890 of each 1,000 persons enumerated in 1810 there survived only thirty-five; of each 1,000 enumerated in 1800, only four, and of each 1,000 enumerated in 1790 only one fifth of one person. Now one can no more assume that 94 per cent. of each 1,000 had native parents because 94 per cent. of

thirty-five, or four survivors, did than one can assume that a bushel of apples is sound simply because a half dozen apples taken from the bushel are sound. In short, we lack knowledge for the years preceding 1810, and possibly 1820. Yet this knowledge is essential to the method of computation employed. How, then, can it be said that of the native whites enumerated in 1920, 41,288,570 were descended from the 3,172,444 whites enumerated in 1790. This figure is further suspect because in no other part of the world has a population of three millions increased twelvefold in 130 years as a result of births in excess of deaths.

If we can not even say that there were 41,288,570 descendants, how can it be asserted that 77 per cent. of these, or 31,803,000, are of British and North Irish origin? The committee of experts who determined the quotas found that of the original 3,172,444 whites 77 per cent. had names that seemed to be British or North Irish in structure. Ergo, 77 per cent. of the forty-one million descendants are British. Such reasoning is most questionable. How can it be known whether a name is British, German or what? The committee admitted this, in part, for at first they held that about 90 per cent. of the names were British. This figure was reduced following protests and further "research." The names were taken, not from original records, but from a general summary published 120 years after the census of 1790.

Even if it were correct to say that 77 per cent. of the names were British it would not follow that 77 per cent. of the descendants were British, for this would assume that the 23 per cent. non-British increased in the same ratio as the 77 per cent. British. This is doubtful. Different nationalities increase at different rates, and the British rate was possibly the lowest, for the New England and Atlantic states, dominantly British in origin for a long time, had a low rate of increase. Hence 30 or more per cent. of the alleged forty-one million descendants may be non-British.

It is even more difficult to estimate the number of grandchildren, great-grandchildren, etc., of British and North Irish immigrants arriving after 1790. First, no immigration records were kept until 1820; those after 1820 for at least fifty years were incomplete. Second, since many non-British immigrants came to this country in British ships and since persons were classed according to the flag of the ship in which they came, the number of immigrants registered as British is too large; thus Scandinavians coming in British ships were classed as British. Third, since there exist very few data on the natural increase of different national stocks and since what data exist show the British to have had the lowest rate of increase it is impossible to assume an equal rate of increase for all nationalities and by a hidden jugglery of figures to estimate that, in 1920, there were 3,728,700 grandchildren, great-grandchildren, etc., of British and North Irish immigrants arriving after 1790.

We have shown the estimate of persons of British extraction to be arbitrary and impossible of statistical justification. One can do likewise for any other country. If it is impossible to determine what part of our population is of a given national extraction it becomes impossible to calculate quotas under the national origins plan. Actually the quotas were computed four times before adoption, and each time they differed. The final British quota is 23 per cent. lower than the original computation; those for Germany, Poland, Czechoslovakia and Irish Free State are respectively 30, 44, 111 and 114 per cent. higher. Could any critic require a more obvious evidence of the statistical unsoundness of the quotas arrived at?

Because of the arbitrary character of the quotas the Senate twice postponed

making the national origins plan effective. As secretary of commerce, Mr. Hoover joined Secretaries Kellogg and Davis in an implied criticism of the plan in a letter to President Coolidge: "We wish it clear that we neither individually nor collectively are expressing any opinion on the merits or demerits of this system of arriving at the quotas." Mr. Hoover vigorously condemned the plan in his acceptance speech. As president he requested the repeal of the plan, which nevertheless was finally adopted despite bitter opposition in the Senate. Mr. Hoover proclaimed the bill a law only because it was mandatory upon him to do so. The adoption of this plan has offended not only national groups in this country but also so-called Nordic nations whose quotas were greatly reduced.

The quotas under the national origins plan have not even the merit of satisfying those who desire a dominantly Nordic stream of immigration. The quotas for Nordic Scandinavia, Germany and Irish Free State have been reduced 63, 49 and 38 per cent. respectively, whereas the quotas of many non-Nordic countries have been increased. Further, since the British did not fill the earlier and smaller quota it follows that this plan will not increase British immigration. Restriction on the basis of the census of 1890 favored the Nordics more than the present plan.

The national origins plan rests upon the assumption that the peoples admitted under it can better be assimilated into the American population. This assumption is false, however. Not nationality but rather an understanding of American traditions, knowledge of the English language, general education and the ability to perform tasks of which we have need are essential to assimilation into the American population. Yet the national origins plan makes no more provision to test the fitness of the immigrants on these grounds than did the previous acts of 1921 and 1924.

The national origins plan violates the cardinal principle of immigration policy, namely, the ability of the United States to absorb more immigrants. We need no permanent immigrants other than skilled professional men and educators. Our population will increase naturally to between 140 and 175 millions within the next fifty years. Why then admit 153,000 unselected Europeans each year, to say nothing of the thousands of non-quota immigrants from Europe or of the 73,154 Canadians and 59,016 Mexicans who came in 1928 and will continue to come, or of those annually smuggled into this country whom Representative La Guardia estimated at 350,000 for Mexico alone? There is little solace in the fact that the last Mexican revolution temporarily reduced Mexican immigration, or that improved border control has reduced illegal entries.

V

What, then, is the United States to do in order to establish a sound immigration policy? A theoretical solution is simple. Putting this solution into effect is equally simple.

First of all, it is necessary to determine statistically whether or not more immigrants are needed. In view of the persistent unemployment the answer would probably be in the negative so far as concerns those other than very skilled artisans, scientists, educators, artists, etc. The United States is not duty bound, as certain Italian thinkers have argued, to relieve the overpopulation of Europe. When America answered in the negative by passing restriction laws, Italy, according to George Young, joined the League of Nations in the hope of obtaining outlet colonies. European overpopulation is a peculiarly European problem to be solved by Europe. By the same reasoning that led us to restrict European immigration we must also restrict immigration from the countries of North America.

Provided it were decided not to admit

other immigrants than artists, scientists, etc., it would be humanitarian to continue the present practice of admitting dependent relatives of immigrants now living here. Temporary admission could be granted to relieve seasonal labor shortage in Maine and the southwest. Other exceptional cases could be settled amicably.

If it were decided that not over 100,000 immigrants were to be admitted annually from all parts of the world precedence would need to be given to dependent but admissible relatives of resident immigrants and to scientists, educators, artists and similar intellectual workers who desire permanent abode in the United States. The remainder would consist of persons able to perform occupational tasks for which the United States had specific need. Nationality would not be made the basis of admission. Instead admission would be allowed each year to the first 100,000, otherwise desirable, regardless of nationality, who satisfactorily passed specially devised psychological and educational tests. These tests would be administered abroad under the supervision of consular officers. Any one seeking to take such a test would have to pay a fee covering every item of expense involved; applicants would thus be limited and no expense would be incurred by the United States. Once admitted the social assimilation of the admitted quota would be fostered judiciously.

If the annual quota were fixed at 100,000, only white nationalities alone ought to be admitted, black and Oriental intellectuals to be excepted, however. If, on the contrary, admission were to be granted only to scientists, educators and artists no distinction ought to be made as to race, color or nationality.

At present there is but a partial trend in the direction of the above suggestions. Already certain preferences are provided for in the issuance of immigration visas. Efforts are being made to restrict immigration from Mexico and Canada. Demands for seasonal labor will probably be observed. F. S. Fitzpatrick, of the U. S. Chamber of Commerce, in an address at the Williamstown Institute of Politics, suggested that an international commission be set up to regulate and select immigrants from Mexico and other Latin-American countries and to adjust their absorption into American industry. To date, however, the notion of optimum population and of the capacity of the United States to absorb immigrants has not affected immigration legislation.

As yet immigration has not, according to Aleš Hrdlička, curator of the National Museum, brought about any physical deterioration in the United States, nor is it likely to.

Economically, however, immigration must be controlled much more rigidly, and along the lines suggested in this article, in order that the American standard of living will not be depressed and that our economic life will not otherwise be harmed.

VIGNETTES OF HENRY EDWARDS AND JOHN MUIR

By J. S. WADE

U. S. BUREAU OF ENTOMOLOGY

ALWAYS the heart of the confirmed collector of insects throbs with joy when he reads such words as these: "In the small box which you sent me are four species new to my collection, and two of these are new to science." These words appear in a letter written on August 25, 1871, by Henry Edwards to his friend John Muir, from whom he had been regularly receiving entomological specimens.

It is easy to visualize the scene: John Muir, the young Scottish naturalist, student and mountain enthusiast, had taken sanctuary in the Yosemite Valley of California, and filled with adoration for its scenic charms at all seasons of the year hardly could be persuaded to leave the spot. With insatiable curiosity and with marvelous constancy and endurance, he spent all his time in exploration and study of nature in grand, solitary places such as this. The association and the cooperation of a man of such type was a veritable godsend to Henry Edwards who, himself, was not only in many respects a kindred spirit but likewise was a man of remarkable and outstanding attributes. Familiarly known among his San Francisco friends as "Harry" Edwards, he was an actor by vocation, though by avocation he was an entomologist. Working in the latter capacity, he had accumulated what was then regarded as one of the largest private collections of butterflies and beetles in the country. The cooperation of two such men in the collection and study of the insects of the High Sierras naturally would be productive of interesting and worth-while scientific results.

It is not only of more than passing interest, but it is of considerable intrinsic value as well, even to-day, to study vignettes of the careers of these individuals and to collate the rather fragmentary and inadequate facts bearing on their contacts with each other which have come down to us. Then, too, it is not unsafe to assume that there probably are scientists of our own day and generation who could profitably ponder lessons to be derived from the excellent example set by these two scientists—men who cooperated or worked together in a common interest during apparently prolonged periods in absolute harmony and friendliness.

An Englishman by birth, Henry Edwards first saw light at Ross in Herefordshire, on August 27, 1830. Little appears on record concerning his childhood and adolescence. It seems that he studied law for awhile in his young manhood, but without evincing any special aptitude for the legal profession. Presently, a combination of circumstances and fondness for commercial enterprise led him into a London counting-house, where Walter Montgomery and John L. Toole were fellow clerks.

Soon he became greatly interested in amateur acting, in association with Montgomery and others. He developed so much talent along this line that he decided, much against the wishes of his parents, to enter upon a professional theatrical career. He made his first appearance as Rudolf in Byron's "Wonder," and in 1853, at the age of twenty-three, he resigned his position as clerk and sailed for Melbourne, Australia, on

a theatrical engagement. In the years that followed he became well known as an actor, serving engagements with different companies in Australia and elsewhere.

By and by he drifted to Peru and Panama, and in 1867 reached San Francisco. About 1877 he made his first appearance in the east at Boston, and finally in 1879 he reached New York City. In that year he was engaged by the late Lester Wallack as a member of his stock company, and became stage manager of the theater. After the disbandment of the Wallack Company in 1889–90, he again revisited his old home in Australia as a manager for A. M. Palmer's "Little Lord Fauntleroy" organization, returning in 1890 to join Augustin Daly's Company.

During all these years he was constantly connected with the stage, until only a short time before his death, when he was compelled to retire on account of illness. His last appearance was in New York in the part of Sir Oliver in "The School for Scandal." Most of the remaining period of his life was spent in the Catskill Mountains in a vain search for health. He died of heart disease, dropsy and other complications in New York City on June 9, 1891.

One of the most interesting of his popular writings which has come to the writer's attention is entitled "A Mingled Yarn: Sketches on Various Subjects," issued by Putnam in 1883, and comprising 157 pages, 12mo, of short sections bearing such titles as "Three Weeks in Mazatlan," "Bubbles from Bohemia" and "Trifles Light as Air." There are brief articles within these dealing with various subjects as, "Shakespeare," "Edwin Adams," "James Hamilton," "Joseph Maguire," "Mid-summer High Jinks," "Two Balloon Voyages," "Agassiz" and "The Church and the Stage." The following extract from the paper on "Shakespeare" is fairly representative of his literary style:

> He [Shakespeare] is preeminently a naturalist, in the broader sense of the term, not the man of mere technical knowledge, of names and terms, of dry classification, whose brain is filled with genera and species, varieties and races, groups and affinities; but one possessed of that faculty of observation (given to but few) even of the meanest things—a power of discovering their varied uses, and pointing out their rank and value in the great chain of nature. The rocks and woods, the trees and flowers, the rolling seas, the calm and the tempest, the sunbeam and the dewdrop, the tiny insect and the giants of the animal world, are alike to him emblems of creative power, and speak to his receptive soul in the divine language of God.

As an entomologist Mr. Edwards had a world-wide reputation and was considered one of the foremost authorities on some groups in that science. He probably will be best remembered by his work on the Lepidoptera of California and the Pacific coast. His excellent papers contain descriptions of many new and interesting species from that region, one of these being "Studies on North American Ægeriidæ." For many years he was deeply interested in entomological bibliography, and his last important contribution was the well-known "Bibliographical Catalogue of the Described Transformations of North American Lepidoptera," a work on which he spent an almost incredible amount of toil and pains—to be fully appreciated only by those who have attempted work of similar comprehensive and long-continued scope. The magazine *Papilio* was edited by him from 1881 to 1883, inclusive, through volumes one, two and three, after which the work passed into the hands of Mr. E. M. Aaron, of whom Edwards wrote with characteristic appreciation at the time he formally relinquished editorship.

Mr. Edwards had membership in many scientific and other societies. He was for some time vice-president of the California Academy of Sciences; he was a life member of the Brooklyn Entomological Society, a member of the Torrey Botanical Club, the Players' Club of

New York and the Bohemian Club of San Francisco; a corresponding member of the Boston Society of Natural History, the San Francisco Microscopical Society, the San Diego Natural History Society and the Belgium Natural History Society. It is easy to see that it was his scholarship and his intense interest in the scientific questions of his day that led him into affiliations with so many of the learned societies, nor do we find that these were perfunctory only, for he regularly attended the society meetings, wrote papers for them and attained to high place in their councils. He also had a great many entomological friends and maintained an extensive correspondence with them. The writer is much indebted to reminiscences of Dr. William Schaus, of the U. S. National Museum, for little word pictures of much interest regarding Edwards, for Dr. Schaus knew him quite intimately, has preserved letters and personal belongings from Edwards and always refers to his association with his friend with an appreciation that does honor to his own discernment and goodness of heart, for it was primarily the aid and encouragement and inspiration received from Edwards during formative years in young manhood that caused Dr. Schaus first to enter upon professional entomology.

Edwards loved his favorite studies quite as much as he did the stage and brought to both an ardor and freshness contagious and perennial. One of his correspondents, writing about him after his death, emphasizes his unvarying kindness and unfailing help to entomologists who were less learned than himself. "I owe much," said he, "to his help and encouragement and shall miss him sorely, though I never saw his face." And it is said that those qualities which so endeared him to a large circle of friends were indeed conspicuous in that face.

His interest in entomology had dated back to the period of his London residence, where under Mr. Doubleday's auspices he commenced the study and collection of insects and there formed the nucleus of the collection that later grew to proportions far beyond any dreams of his earlier years. He spent much money over a long period of years toward the increase of his collection of insects and devoted most of his leisure hours very happily to this, his favorite study.

It is obvious that his extensive travels afforded him many rare opportunities for collecting and otherwise obtaining a vast lot of material not only for his collection but for study and subsequent use in his writings. At the time of his death his collection consisted of about 250,000 specimens of insects of all orders from many parts of the globe. It contained the types of the greater number of the species he described, about four hundred and fifty in all, except a few which were deposited in museums and other collections. It also contained a number of Grote's types of Noctuidae and Pyralidae and many of Fish's types of Pterophoridae and the types of species proposed by other writers. It likewise contained the unique pair of *Onitícellus californicus* and many other uniques, oddities and rarities of considerable value. A significant paragraph by Dr. Morris K. Jesup regarding this collection appears in the "Annual Report" of the American Museum of Natural History for 1891, on page 12:

Efforts are being made under the auspices of Mr. A. M. Palmer and others of the dramatic profession and friends of the late Mr. Edwards to secure the widely known "Harry" Edwards collection and library. This collection numbers about 250,000 specimens and about 40,000 different species gathered from various parts of the world. Although consisting chiefly of butterflies and moths and beetles, all orders of insects were represented. On account of the great number of type specimens, this collection is considered by good authorities as one of the best in existence, and is also one of the largest private collections in the world. The library accompanying the collection possesses over 500 volumes and about 1,200 pamphlets.

At the time when the "Annual Report" was issued in the following year (1892) the ambition had become realized and there appears the following triumphant entry on page 10 of that publication:

This Department has been greatly enriched and augmented by the acquisition of the well-known collection gathered by the late Henry Edwards, which was partly purchased by friends of the deceased. The collection consists of about 250,000 specimens of insects from all parts of the globe, and is extremely rich in material from this country.

Some idea of the scope and magnitude of the collection and the place it occupied in the program of the museum activities may be gained from still another brief quotation from the "Annual Report" for 1893, on page 12, as follows:

The butterflies and moths of the Henry Edwards collection were transferred to cases constructed for their reception and these, as also similar material from the Elliot and Augus collections, are now freely accessible and frequent use is being made of them by students and specialists. Satisfactory progress has been made in the work of cataloguing and numbering the specimens.

William Frederick Badè in his biography of John Muir records in a footnote that his attention had been directed by Mr. Frank E. Watson, in charge of the Lepidoptera section of the American Museum, to the fact that in 1881 the butterfly *Thecla Muiri* was named by Edwards in honor of his friend. Apropos of this, we find that in *Papilio*, volume 6, page 54, 1881, Edwards writes: "I have named this exquisite little species after my friend John Muir, so well known for his researches into the geology of the Sierra Nevada, who has frequently added rare and interesting species to my collection."

Through courtesy of the officials of the American Museum of Natural History in New York, the writer has been permitted to examine the record books, correspondence files and Mr. Edwards' other literary remains now forming part of the permanent collections of that institution. To his disappointment no records were found in this accumulated mass that would throw light on the beginning of the friendship between Edwards and Muir, nor has there been definitely determined the extent of the material obtained nor the exact period during which Muir made collections for him in the Sierras. This seems singularly unfortunate as it would be a matter of considerable interest if at least a little more information bearing on these matters were available to students.

In view of the association of these men and the subsequent deposit in the American Museum of Natural History of the collection over which they had spent so much labor and so many hours of happy comradeship, it seems singularly appropriate that its halls should contain in a place of conspicuous honor the splendid bust of John Muir in marble modeled by Malvina Hoffman. Perhaps his labors with Edwards alone, had there been no greater reason therefor, would have rendered him fully deserving of a worthy place in such an educational institution —probably the most far-reaching in its influence of any of its kind in all the world.

Fortunately, through the researches of Dr. Badè and others, this sketch of Muir's career can be made much clearer and less fragmentary than that of Edwards. It is not an extravagant use of language to say that in many respects Muir was unique; not only was he an extremely stimulating and remarkable man, but it is not trite to say that there was no other quite like him. He possessed through aid of memory, observation and fancy that grace and magic of style for which most writers toil in vain. While his writings at times remind one of Thoreau or Burroughs or some one of the other famous writers who have popularized natural history studies, yet he is always distinctive in his simplicity, his gentleness, his wholesomeness and his

intensely human appeal. Entirely aside from the pleasure derived from his word pictures of natural phenomena and the vernal fragrancy with which they are phrased, there are thousands who have gained from his philosophy of life inspiration for renewed endeavor and have been refreshed and stimulated thereby, so as to be able to take up anew and "carry on" what may be to many of them a daily burden of misfit and drudgery.

The first eleven years of Muir's life were spent at Dunbar, Scotland, where he was born on April 21, 1838. His father, being religious in a most offensive manner, was a dour, morose man, having an amazing rigidity of prejudice and an almost unbelievable austerity and lack of common humanity in dealing with his children, with the result that their little lives were rendered unnecessarily harsh and bitter and loveless. The life of a Scottish peasant's child in that bleak climate in a remote country village afforded only the most limited opportunities for early self-improvement; but there is a less gloomy side to the picture, for fortunately there was a bond of affectionate intimacy between the boy and his mother, whom he later in life characterized as a "representative Scotch woman, quiet, conservative, of pious affectionate character, fond of painting and poetry"—one who wrote poetry in her girlhood. Then, too, there was a maternal grandfather, David Gilrye, who took long walks into the country with his small grandson and lovingly imparted to him much information on natural phenomena that undoubtedly laid the foundations of his life-long interest therein. Fleeting glimpses of his childhood reveal him as a "vivid, auburn-haired lad, with an uncommonly keen and inquiring pair of eyes."

In 1849 the family came to America and located on the frontier in a new settlement near Portage, Wisconsin, where two large farms in succession were bought, cleared and brought under cultivation. In this work the lad bore a proportionate share, driven on in stern discipline by an inexorable father who could see no possible success in life for any one apart from the most intense manual labor on a farm and in care of live-stock. Muir's book entitled "The Story of My Boyhood and Youth" contains some exceedingly vivid, unflattering and effective word pictures of that important formative period of his life, and is an indispensable document to all students of the adolescence of genius.

It should not be a matter of surprise that, just as many another lad has been driven away from home by a father lacking in sympathy for and understanding of him, so young Muir bided his time and in 1860, at first opportunity, made his plunge into the big outside world. In the period between 1860 and 1866, after leaving home, he was engaged in teaching; was for four years a student on a self-supporting basis at the University of Wisconsin; was a wandering free-lance student of botany in various parts of Wisconsin and Iowa, and was making a sojourn in Canada during which he spent some time in Toronto and the sections around Lake Ontario, Niagara Falls and Georgian Bay. In 1866, however, because of loss of his position through a fire in a broom-handle factory where he had been employed, he returned to Wisconsin.

In May of that year we find him proceeding alone on foot from Indianapolis, Indiana, on the afterwards famous "Thousand-mile Walk to the Gulf," a detailed account of which he later wrote in his own inimitable way. The temptation is great to quote lavishly from this, but space limitations are imperative. One can only emphasize that all those who have not yet read the book have ahead of them a distinct literary treat. He proceeded leisurely, study-

ing and collecting botanical and geological specimens, through the states of Kentucky, Tennessee, North Carolina, Georgia and Florida; he had some unique experiences in Savannah and he almost perished during an illness at Cedar Keys, Florida, his survival being due to the care given there by some chance acquaintances, named Hodgson. On recovery he sailed to Havana, later to New York, then presently to Panama and soon afterward to California.

The year 1869 was a very full one for Muir, as it was on March 27 that he first reached San Francisco, an event that marked the beginning of a career that was destined to become epochal for both man and the state, and the contemplation of the far-flung effects of which surely haunt human imagination. There was nothing spectacular about the California beginning, however, for the young naturalist drifted slowly and a bit aimlessly through Oakland, San José, the San Joaquin plain and on to Coulterville in varied occupations, such as the breaking of horses, the running of a ferry-boat, the shearing of sheep. Soon he was herding sheep near Snelling at thirty dollars per month, an occupation from which presently he advanced to that of sheep inspector in the Yosemite country. It was at about this time that he first formed the acquaintance with Professor Carr, of the University of California, and also made his first important excursion into the High Sierras—a modest beginning to a brilliant Yosemite career.

With faithful note-book always at hand and with unwearied toil he was constantly on the lookout for what might be learned; he observed the deposition of the snow upon the rocks and trees, studied the individual crystals with a hand lens, detected the squirrel examining its stores beneath the drift and became intimate even with wild sheep that found shelter and protection near his camp. Fortunately passages culled here and there from letters to his various friends[1] or from his writings furnish clues to or at times give lively word pictures not only of his activities during this period of his life but also of his trends of thought. A few illustrations must suffice:

> I expect to be entirely alone in these mountain walks, and notwithstanding the glorious portion of daily bread which my soul will receive in these fields where only the footprints of God are seen, the gloamin' will be very lonely, but I will cheerfully pay this price of friendship, hunger, and all besides.

And:

> When in the woods, I sit at times for hours, watching birds or squirrels or looking down into the faces of flowers, without suffering any feeling of haste. Yet I am swept onward in a general current that bears on irresistibly. When, therefore, I shall be allowed to float homeward, I dinna, dinna ken, but I hope.

Or:

> I knew that mountain boulders moved in music, so also do lizards, and their written music, printed by their feet, moving so swiftly as to be invisible, cover the hot sands with beauty wherever they go.

Again:

> The very finest, softest, most ethereal purple hue tinges, permeates, covers, glorifies the mountains and the level. How lovely then, how suggestive of the best heaven, how unlike a desert now! While the little garden, the hurrying moths, the opening flowers and the cool evening wind that now begins to flow and lave down the gray slopes above heighten the peacefulness and loveliness of the scene.

His sensitiveness to the touch of beauty and his felicity of description often are manifested:

> The grand priest-like pines held their arms above us in blessing. The wind sang songs of welcome. The cool glaciers and the running crystal fountains were in it. I was no longer on but in the mountains—home again—and my pulses were filled. On and on in white moon-

[1] All previously published passages from Muir's letters are here used by permission of Houghton Mifflin Company and taken from Badè's "Life and Letters of John Muir."

light spangles on the streams, shadows in rock hollows and briery ravines, tree architecture on the sky more divine than ever stars in their spires, leafy mosaic in meadow and bank. Never had the Sierras seemed so inexhaustible—mile on mile onward in the forest through groves old and young, pine tassels overarching and brushing both cheeks at once. The chirping of crickets only deepened the stillness.

Again, he is ever alive to the beauties and novelties of the scene:

Meadows grassed and lilied head-high, spangled river reaches, and currentless pools, cascades countless and untamable in form and whiteness, groves that heaven all the Valley!

He had a vivid appreciation of the natural phenomena around him, and apparently fatigue never came to mar the values of the day:

Here I lay down and thought of the times when the groove in which I rested was being ground away at the bottom of a vast ice-sheet that flowed over all the Sierra like a slow wind—my huge campfire glowed like a sun—a happy brook sang confidingly, and by its side I made my bed of rich, spicy bough, elastic and warm. Upon so luxurious a couch, in such a forest and by such a fire and brook, sleep is gentle and pure. Wild wood sleep is always refreshing; and to those who receive the mountains into their souls, as well as into their sight, living with them is clean and free—sleep is a beautiful death, from which we arise every dawn into a new-created world, to begin new life in a new body.

Here and there a star glinted through the shadowy foliage overhead, and in front I could see a portion of the mighty canyon walls massed in darkness against the sky; making me feel as if at the bottom of the sea. The near soothing hush of the river joined faint broken songs of cascades. I became drowsy and on the incense-like breath of my green pillow, I floated away into sleep.

Or occasionally there are aspects that give something of ideal beauty:

The night comes on full of change, sounds from birds and insects new to me, but the starry sky was clear and came arching over my lowland nest seemingly as bright and familiar with its glorious constellations as when beheld through the thin crisp atmosphere of the mountain tops.

His was a soul of an idealist that could translate the carol of a robin heard in a distant mountain of the High Sierras as saying, "Fear not, for only love is here," and he it was who could say, "A crust by a brookside out on the mountains with God is more than all." He expressed his appreciation of God in nature in language that sometimes reveals extraordinary powers of insight and description, and the style takes on at times a haunting beauty:

While we were there, clouds of every texture and size were held above its flowers and moved about as needed, now increasing, now diminishing, lighter and deeper shadow and full sunshine in small and greater species, side by side as each portion of the great garden required. A shower, too, was guided over some miles that required watering. The streams and the lakes and the rains and the clouds in the hand of God weighed and measured myriads of plants daily coming into life, every leaf receiving its daily bread—the infinite work done in calm effortless omnipotence.

A deeper note is sounded in a letter to still another friend when he says:

We are back to our handful of hasty years half gone, all of course for the best did we but know all of the Creator's plan concerning us. In our higher state of existence we shall have time and intellect for study. Eternity, with perhaps the whole unlimited field of God as our field, should satisfy us, and make us patient and trustful, while we pray with the Psalmist, "So teach us to number our days that we may apply our hearts unto wisdom."

His philosophy of life enabled him to write to his old friend, Mrs. E. S. Carr, concerning certain profound changes that had come into her life:

God will teach you as He has taught me that the dear places and dear souls are but tents of a night; we must move on and leave them, though it cost heart breaks. Not those who cling to you, but those who walk apart, yet ever with you, are your true companions.

In a somewhat like connection it was Badè who said of him: "The course of his bark is directed by other stars than theirs, and he must be free to live by the laws of his own life." For, as Muir says:

I understand perfectly your criticism in the blind pursuit of every scientific pebble, wasting

a life in microscopic examinations of every grain of wheat in a field, but I am not so doing. The history of this vast wonderland is scarcely at all known, and no amount of study in other fields will develop it to the light.

It is only here and there in the correspondence examined that statements apear more or less random in character pertaining to the actual details of the collection and shipment of specimens from Muir to Edwards. The extracts therefrom which follow are fairly representative of them.

On August 10, 1871, Muir wrote from Yosemite as follows:

Dear Edwards: I sent you the few flies and bugs which I collected on the Summit Mts. Yesterday by Mr. King, I told him that if it would much delay him to see you he might leave them at Dr. Carr's. Mr. Reilly, a photographer, was in our party; one of the most irritable & unreposable of men & his puny bundlet of frizzling cares prevented me from doing much for you. The butterflies are mostly from the gravelly slopes of Mt. Hoffman; altitude of 9,000 to 10,500. They are quite abundant there but are small, exactly corresponding to the dwarfy flowers upon which they feed. You charged me to look carefully for a white butterfly with red spots. I think that you will find two of this species among those I send. They are from Mt. Hoffman & are not rare, but are very hard to capture. Here is another white fellow that I caught yesterday in the River Canyon below Yosemite. The two small crimson butterflies are from Cathedral Peak, south from Tuolumne Meadows. They are very rapid and restless & appear to like nothing better than to beat about untranquilly in the high winds which constantly sweep the bare bald summits of this whole region. I was surprised at the scarcity of butterflies in the flowery plains about Mono Lake. I don't think that they like so much alkali & volcanic ashes. Still I think it strange that butterflies should be unwilling to dwell where there are such large congregations of contented flowers. I fear that the flies I send are too badly bruised to be of use to you as specimens, but you will at least learn by them that such creatures do dwell upon our high mountains, sometime I shall send you better ones. I captured that large moth here in my hang nest. I don't want to kill any more of that kind because in dying he gasped & throbbed & almost shouted, Murder. John Dennis, who resides at Coulterville, collected some butterflies which he said he would send you. If any of these are rare tell me & I will take pains to catch some more for you. I had some grand glacier lessons among those glorious half in heaven peaks & spent many a rapturous hour with the happy plant children that have home there. I am not working for Hutchings now. Hereafter I mean to make guiding my business & spend all my leisure among Nature's glorious manuscript of mountains.

In a letter to his friend, Mrs. E. S. Carr, August 13, 1871, he says:

I suppose you have seen Mr. King, who kindly carries some butterflies for Mr. Edwards. I thought you would easily see him or let him know that you had his specimens. I collected most of them upon Mount Hoffman, but was so busy in assisting Reilly that I could not do much in butterflies. Hereafter I shall be entirely free.

On February 22, 1873, he wrote to Asa Gray:

Our winter is very glorious. January was a block of solid sun-gold, not of the thin frosty kind, but of a quality that called forth butterflies and tingled the fern coils and filled the noontide with a dreamy hum of insect wings.

Again on March 30, 1873, he wrote to Mrs. Carr:

Oftentimes when I am free in the wilds, I discover some rare beauty in lake or cataract or mountain form, and instantly seek to sketch it with my pencil, but the drawing is always enormously unlike the reality. So also in word sketches of the same beauties that are so living, so loving, so filled with warm God, there is the same infinite shortcoming. The few hard words make but a skeleton, fleshless, heartless, and when you read, "the dead bony words rattle in one's teeth." I sent Harry Edwards the butterflies—did he get them?

Occasionally vague hints were thrown out or catchwords in lightsome caprice were mentioned which were significant of the free and easy comradeship existing between these friends, and make one long to know more details regarding it, as, for example, the joke behind the cryptic reference to Edwards in Muir's letter to his friend, Mrs. Carr, in September, 1874:

While I stood with these dear old friends, we were joined by a lark, and in a few seconds more Harry Edwards came flapping by with spotted wings. Just think of the completeness of that reunion—twenty—Hill Hollow, Hemi-

gonia, Eriogonum, Lark, Butterfly, and I lavish outflows of genuine Twenty Hill Hollow sun-gold.

Again Muir wrote in graceful rhetoric without conscious art from the Yosemite to Edwards under date of June 6, 1872:

Dear Edwards: Your bundle of butterfly apparatus is received. You are now in constant remembrance, because every flying flower is branded with your name. I shall be among the high gardens in a month or two & will gather you a good big handful of your favorite painted honeysuckers & honeysuckles. I wish you all the deep far-reaching joy you deserve in your dear sunful pursuits.

Muir was not so engrossed in collecting Lepidoptera as to be entirely oblivious to other insect forms, nor were interest or fancy lacking when opportunity offered for making observations upon or of performing experiments with them, as witness his letter to Mrs. Carr in November, 1874:

At length a gray grasshopper rattled and flew up, and the truth flashed upon me that he was the complimentary embroiderer of the lizard. Then followed long careful observation, but I never could see the grasshopper until he jumped, and after he alighted he invariably stood watching me with his legs set ready for another jump in case of danger. Nevertheless I was soon made sure that he was my man, for I found that in jumping he made the shallow pits I had observed at the termination of the pattern I was studying. But no matter how patiently I waited, he wouldn't walk while I was sufficiently near to observe. They are so nearly the color of the sand. I therefore caught one and lifted his wing covers and cut off about half of each wing with my penknife, and carried him to a favorable place in the sand. At first he did nothing but jump and made dimples, but soon became weary and walked in common rhythm with all his six legs, and my interest you may guess while I watched the embroidery —the written music laid down on a beautiful ribbon-like strip behind. I glowed with wild joy as if I had found a new glacier—copied specimens of the precious fabric into my notebook and strode away with my own feet sinking with a dull crounch, crounch, crounch in the hot gray sand, glad to believe that the dark, cloudy vicissitudes of the Oakland period had not dimmed my vision in the least. Surely Mother Nature pitied the poor boy and showed him pictures.

Still another whimsical paragraph, also from a letter, is suggestive of his varying moods:

Yesterday I began to try to cook a mess of bees, but have not yet succeeded in making the ink run sweet. The blessed brownies winna buzz in this temperature, and what can a body do about it? May be ignoramus is the deil that is spoiling—the—the—the—broth—the nectar, and perhaps I ought to go out and gather some more Melissa and thyme and wild sage for the pot.

Especial emphasis has been here placed upon and fuller quotations have been made from the records of the ten years from 1868 to 1879 because it was during that period that Muir made the most extensive as well as the most interesting collections for his friend. Between his excursions in the Yosemite he spent much time either while at camp or at San Francisco in writing for various periodicals including the recently established *Overland Monthly*. Friendly visitors to his domicile during these years or friendships formed by mutual friends or by correspondence included such individuals as Mark Hopkins, Joseph LeConte, Ralph Waldo Emerson, Grace Greenwood, Therese Yelverton, Asa Gray, Mark Twain, Joaquin Miller, Edward Rowland Sill, Ambrose Bierce and Bret Harte. During that decade he also discovered sixty-five residual glaciers in the High Sierras; made an intensive study of the trees of the Pacific Coast, including the *Sequoia gigantea*; made expeditions to Mount Hamilton and Mount Shasta; descended the Sacramento River in a small skiff; made trips down the San Joaquin and Merced Rivers; went with the U. S. Coast and Geodetic Survey into Nevada and Utah and explored the Lake Tahoe vicinity, and in 1879 made his first trip to Alaska and explored some of the upper courses of the Yukon and Mackenzie Rivers. The following winter he was again in San Francisco busily engaged in literary work, and in April, 1880, he married Louie Wanda Strentzel, of Martinez, California, and thereafter for some ten years was engaged in horticultural ac-

tivities at that place, especially in the development of a fruit ranch in the Alhambra Valley near Martinez, inherited by his wife. During this period, however, there were interspersed two more trips to Alaska, one of them being the now famous expedition of the *U. S. S. Corwin*.

The extent of his intimacy with Edwards during all these other activities appears vaguely defined after all these years, though it is evident that in a rather casual way they kept more or less in touch with each other, as witness a letter from Muir to Edwards from Martinez, California, on December 20, 1880:

My dear Harry Edwards, Your kind letter reached me after I had returned from my second visit to Alaska, but I shall most likely go to that far icy country yet once more & shall gladly do what little I can for you now that I have your address. There is a minister residing in the territory at Fort Wrangel, whom I tried to persuade last summer to begin collecting insects. I think you might find it to your interest to write to him on the subject. I told him about you & John LeConte, of Philadelphia. I saw but few butterflies among the many flowers, though as you say all of them must needs be more or less interesting to scientists. I am glad to see that you are still at work in your delightful studies that keep your heart young & that you have not forgotten me. I had hoped to have been east before this time, but my studies drive me like mist & thistledown wheresoever they will. I do hope most devoutly that Emerson will not go away before I see him again. You will doubtless be interested to learn that Ina Coolbuth's poems are to appear in permanent book form ere long. John Carmany is printing them. Ina is still in the Oakland Library though she has long wished to escape from it, as she does not at all like her position there. Thanks for your good wishes as to my marriage all goes well & so naturally that I seem to have been married always. You are sadly missed in San Francisco though I have no doubt you have a much more congenial field where you now are. I shall always be delighted to hear of your happiness. My wife desires to be remembered to you. She speaks of the pleasure she had in seeing you with Modjeska, who is a countrywoman of hers.

After attaining a competency Muir sold the ranch in 1891 and thereafter devoted himself to travel and to a continuation of literary pursuits. In 1884 he was again in the Yosemite with his wife and little daughter, and in 1885 he revisited his boyhood home in Wisconsin. In 1887–1889 he wrote "Picturesque California" and made expeditions to Vancouver, Mount Hood, Mount Rainier, Spokane Falls and the Puget Sound Region, made additional trips into the Yosemite and the High Sierras and wrote extensively for the *Century Magazine*.

He wrote much during those years for newspapers and periodicals urging the formation of national parks, and the establishment of the Yosemite on October 1, 1890, was in great part due to his efforts. Presently in 1890 he was again in Alaska, this time in exploration of Glacier Bay and the now famous Muir Glacier named after him. The following year he was engrossed in work on the Sequoia National Park and the first of the great forest reserves, and on June 4, 1892, he became president of the newly organized Sierra Club, an office which he held for some twenty-two years. In 1892 another visit was made to Wisconsin, a trip that later included the World's Fair at Chicago, New York, West Point, Garrison-on-Hudson and Boston. He then proceeded to England, Scotland, Ireland and other European countries.

The years following the publication in 1894 of his book on "The Mountains of California" were crowded with events; there were more scientific expeditions to the Yosemite and a trip to the Black Hills of South Dakota. There was a trip to Madison, Milwaukee, Indianapolis, Chicago, New York and Boston. In 1897 there followed another Alaska expedition. Sections of the Southern Alleghenies, North Carolina, Tennessee, Georgia and Alabama were studied, and New York, Boston and the Berkshire Hills were revisited. Then in 1899 came the Harriman Alaska Expedition and the publication of two volumes entitled

"Stickeen" and "Our National Parks." These events were followed in 1904 by a scientific expedition to various parts of Europe, Asia, Siberia, Manchuria, Japan, India, Egypt, Ceylon, Australia, New Zealand, the Philippine Islands, Hong Kong and the Hawaiian Islands.

An almost overwhelming sorrow came into his life on August 6, 1905, in the death of his wife. The following year he became engrossed in activities urging the formation of the Petrified Forests of Arizona into a national monument, and still later he became involved in a bitter controversy in connection with the conservation of forest areas in California, known as the Hetch Hetchy Valley Fight, which continued for several years. The volumes from his pen entitled "The Mountains of California" appeared in 1910. Shortly thereafter he embarked upon a trip to South America and spent considerable time in the Amazon country of Brazil, later going on in 1911 to South Africa. His volume on "The Yosemite" appeared in 1912. Presently he was again at Garrison, New York, immersed in writing up his Alaska notes for publication and in composing "The Story of my Boyhood and Youth." In the winter of 1914 he experienced a very severe attack of grippe, this being followed by pneumonia, and he passed away at the age of seventy-six on December 24, 1914.

The book entitled "Travels in Alaska" on which he had bestowed so much time and pains was issued that same year, and posthumous "Letters of a Friend" and "Prose and Letters" appeared in 1915. He was a member of the American Academy of Arts and Letters and a number of other similar associations, and was president of the Sierra and the Alpine Clubs. He received honorary degrees from Harvard, Yale and the University of Wisconsin and California. In addition to being for many years an outstanding champion of the cause of forest preservation and the establishment of national reservations and parks, we have seen that he always manifested deep interest in practically every phase of the physiography and the natural history of the Pacific Coast.

Much has been written of friendship and its felicities, but citations like this from concrete examples in actual biography are of greater worth than many abstractions. Like the flower in the crannied wall, vignettes of this character from human lives, no matter how humble or obscure, if faithfully reproduced, not only can be made interesting and valuable, but can take on a meaning beyond reach of finite language; therefore, no apology need be suggested for dealing with this phase of biography, for the possibilities become endless. As nature at the springtime season comes into new life under the beams of the sun, so human souls are warmed and expanded under the influence of real and genuine friendship. They become more truly conscious of the powers treasured up within. Admirable qualities in another do not overwhelm, but, happily, awaken corresponding nobility. The ties created by such associations are enduring, and souls thus stimulated bind themselves together with peculiar affection. After a long association and intimacy of such kind as here has been considered, there was scarcely need of speech to communicate sympathy; the fellow feeling had its own language and its own spirit and permeated an otherwise prosaic message: "In the small box which you sent to me are four species new to my collection, and two of these are new to science." Such is the blessed wealth of many human hearts that they continually run over with affection for their friends—affection that not only brings with it consideration, patience and forbearance for others having like tastes, but presently extends to greater charity for all mankind. In the mutuality of such tastes and interests there is more abundant life and increase in permanent happiness.

A person having the gift of making and keeping friends and who proves worthy of having friends is a millionaire at the treasury of love.

MINUTE ANIMAL PARASITES OF MAN

By Professor ROBERT HEGNER

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FEW people realize what a vast number of minute animals, called protozoa, inhabit the earth. This is largely due to the fact that these organisms are microscopic in size and thus do not come within the experience of any except biologists, and most of these have but a casual acquaintance with members of the group. We are accustomed to think of man as the dominant animal on the surface of the earth to-day, and this is correct when considered on the basis of certain criteria; but, in several respects, the Protozoa are and perhaps always will be dominant—these are in numbers of species and in numbers of individuals belonging to each species. Protozoa are called unicellular organisms because most of them are made up of but a single cell. They are able, however, to perform with this single cell all the fundamental processes characteristic of higher animals that make it possible for them to maintain themselves in their environment and also to maintain their numbers. The latter is accomplished by the process of reproduction, which, in most species, is a comparatively simple division of the parent into two daughter cells; these, after a short period of growth, divide in turn into offspring. The parent thus loses its identity at the time of reproduction and its body is equally divided between its two immediate descendants. Inasmuch as growth is often very rapid and division may occur many times in the course of a single day, the number of offspring that may result from the reproduction of one individual protozoon reaches in a few days an enormous total.

The habitats of protozoa are numerous and varied. All of them require one environmental factor, namely, moisture, since they die immediately if they become dry. Most biologists are content to study the protozoa they find in fresh water or in the sea. Many species and enormous numbers of individuals, however, live in the soil to a depth of several feet, and a still larger group live inside other animals and plants. The latter are usually called parasites, although only a small proportion of them are known to injure their hosts perceptibly. The number of species and number of individuals belonging to the parasitic protozoa may be realized when it is stated that almost every species of animal thus far examined has been found to be parasitized by one or more distinctive species, and that a single animal may contain billions of individuals of a single species. Man is no exception. Human beings have probably been examined for protozoon parasites more diligently than has any other animal. Protozoologists differ slightly with respect to the number of "good" species that occur in man, but the most recent studies indicate that there are about twenty-five. These belong to all the four large groups into which the protozoa are divided: (1) amebae, (2) flagellates, (3) ciliates and (4) sporozoa. Apparently no antagonism exists among these protozoa, and one person may be infected at one time with several blood-inhabiting species and two or three or more intestinal forms.

The ameba that is best known to biologists is *Amoeba proteus,* a species that lives in fresh-water ponds. It is often described as a shapeless mass of protoplasm containing a nucleus. Changes in shape are due to the flowing out of false feet or pseudopodia. Human beings are infected with six different species of amebae; one lives in the

mouth and the other five in the large intestine. The species that lives in the mouth is known as *Endamoeba gingivalis* (Fig. 1a). It lives in the gingival spaces at the base of the teeth and is present in probably 50 per cent. of the general population. Since transmission no doubt takes place during kissing, every one at some time in his life is liable to become infected. The reason that infection is not more wide-spread is no doubt due to individual resistance

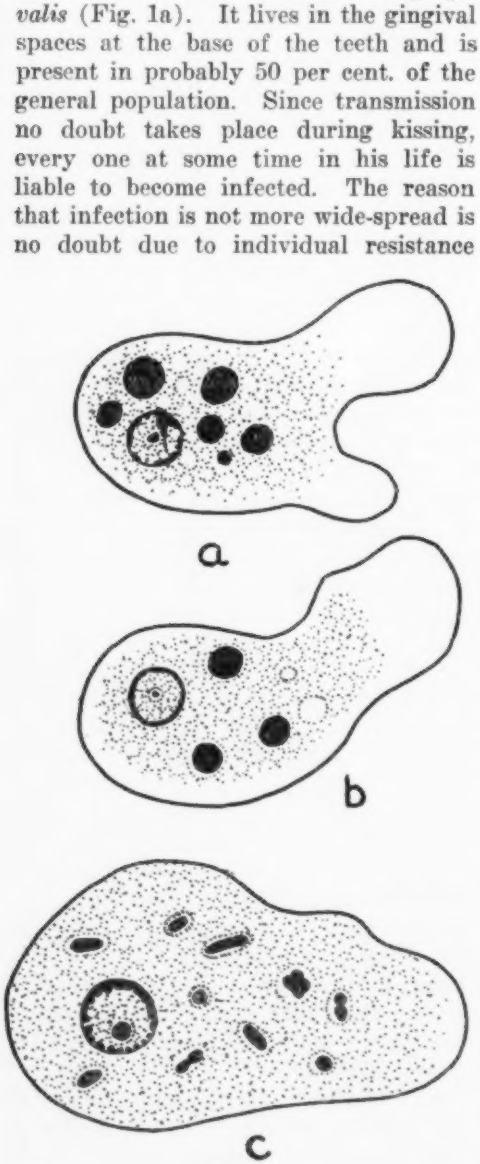

FIG. 1

rather than to freedom from contamination. It is of interest to note that this species, which is transmitted directly by contact, does not include in its life-cycle a cyst stage, such as is characteristic of the amebae of the human intestine which must pass part of their lives outside of the body of their host. Some years ago *Endamoeba gingivalis* was accused of causing pyorrhea alveolaris, but more recent studies indicate that it is really harmless.

A large proportion of human beings also harbor in their mouths a flagellate known as *Trichomonas buccalis.* This species is likewise transmitted by contact and appears to be harmless. Human beings with diseased mouths are, however, more frequently infected than those with healthy mouths, and there is still a possibility that this flagellate is a pathogenic organism.

No protozoa are known to inhabit the human stomach, but about 10 per cent. of the general population are known to be infected by a flagellate, *Giardia lamblia* (Fig. 2a), that lives in the anterior portion of the small intestine. This peculiar protozoon is bilaterally symmetrical, and its two nuclei resemble eyes. Its most prominent feature is a sucking disk which occupies a large part of the ventral surface and enables it to attach itself to the epithelial cells of the intestinal wall. This sucking disk enables this species to maintain its position in the small intestine against the force of peristalsis which tends to carry it downward. Physicians have reported large numbers of giardias in patients suffering from diarrhea in whom no other cause of this intestinal disturbance could be found, and hence believe that the flagellates are responsible for the condition observed. Whether or not such a disease as flagellate diarrhea really exists, however, is still in doubt.

Another inhabitant of the small intestine of man is a sporozoon, *Isospora hominis,* that has been reported from various parts of the world but seems to be rare wherever it occurs. This species penetrates the cells of the intestinal wall where it undergoes growth and both asexual and sexual reproduction. The

final results of the latter are resistant bodies called oocysts which pass out with the excretory products. This human sporozoon is known only in the oocyst stage and we must construct its life-cycle within the body on the basis of our knowledge of the life-cycles of similar species in cats and dogs. *Isospora hominis* is pathogenic and is responsible for a diarrheic condition but is not an ordinary cause of death and is too rare to be of much importance.

The large intestine of man seems like a little world created for protozoan parasites to live in. Here occur five species of amebae, four species of flagellates and one ciliate. The amebae vary with respect to the frequency of their presence and to their relations to their host. The only species known with certainty to be pathogenic is *Endameba histolytica* (Fig. 1b). This species invades the intestinal wall where it produces ulcers. Dysentery, often fatal, results. About 10 per cent. of mankind are infected, but in most cases the human body seems able to repair the damage as rapidly as it is done and are therefore said to be in the "carrier" that are at work in the intestinal wall may enter capillaries and be carried in the blood stream to other parts of the body. Where conditions are favorable, infections are set up. Thus in a large proportion of cases of amebic dysentery, liver abscesses due to the amebae are also present. Abscesses in the lungs, spleen, brain, etc., may also be the result of amebic activities. Fortunately, there are effective methods of treating amebiasis, such drugs as emetin, yatren and stovarsol having been developed for this purpose.

The other four species of amebae inhabiting the human large intestine are considered to be harmless. Two of these species are of very frequent occurrence: *Endamoeba coli* (Fig. 1c) is present, on the average, in about 50 per cent. and *Endolimax nana* in about 25 per cent. of the general population. The other species, *Iodamoeba williamsi* and *Dientamoeba fragilis*, are comparatively rare.

Two species of flagellates that live in the large intestine are rather common but the other two species are seldom encountered. *Trichomonas hominis* (Fig. 2b) appears to vary greatly in its

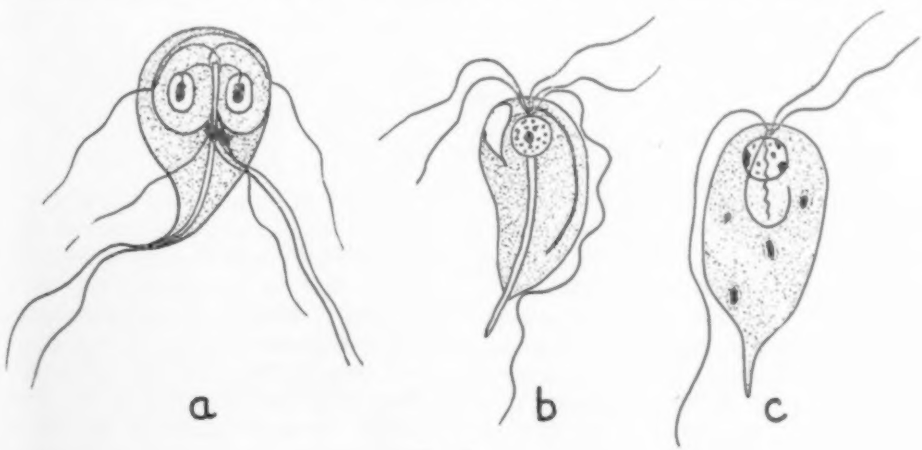

Fig. 2

condition, a carrier being a person who is infected and passing infective stages but does not exhibit symptoms. Amebae incidence in various parts of the world. In tropical America the writer found 20 per cent. of the inhabitants to be in-

fected, whereas in other localities less than 5 per cent. have recognizable infections. This may be due to differences in diet and in sanitary conditions. *Chilomastix mesnili* (Fig. 2c) is likewise a common intestinal flagellate, being present in about 10 per cent. of the general population. Both these species have, as in the case of *Giardia lamblia,* been accused of causing flagellate diarrhea but have not yet been found guilty beyond reasonable doubt. The rare flagellates of the large intestine are *Tricercomonas intestinalis* and *Embadomonas intestinalis.*

A single species of ciliate, *Balantidium coli,* rarely occurs in the large bowel. It resembles very closely in size and structure the common *Paramecium caudatum* of fresh water. Most persons who are infected with this protozoon seem not to be injured by it, but occasionally the organisms penetrate the intestinal wall and bring about the formation of ulcers and produce dysenteric symptoms. No specific treatment is known, although some success seems to have been obtained by regulating the diet and administering the drug named stovarsol.

In the group with the intestinal protozoa is usually included a flagellate, *Trichomonas vaginalis,* which occurs in the vagina of a large percentage of women and has been recorded from the urinary tract of a number of men. This species is believed by many physicians to be pathogenic, although it has not been incriminated with certainty.

Besides the fifteen so-called intestinal protozoa described above there are nine blood-inhabiting protozoa and a single species that has been recorded in a few cases from the muscle tissue of man. This muscle parasite is a sporozoon of the genus *Sarcocystis.* How it reaches human muscle is unknown, but it has been suggested that it is a normal parasite of some lower animal that rarely finds its way into human beings where it occupies a "blind alley" from which it is never able to escape.

The blood-inhabiting protozoa of man are among the most important of all disease-producing organisms. The three species of malaria parasites occur throughout a large part of the tropical and subtropical regions of the earth. The three species of trypanosomes are restricted to certain parts of tropical Africa and tropical America, and the three species of leishmanias are prevalent in Asia and the Mediterranean region and also in parts of tropical America. Malaria (Fig. 3a) has been for many years and still is the most important of all tropical diseases. Theoretically it is easy to control because we know that it is transmitted by the females of certain species of mosquitoes, and we possess in quinin and plasmochin two drugs that are very effective in destroying the organism in the human body. In such places as Havana and the Panama Canal Zone it was found possible to eradicate malaria because there were no restrictions as regards authority, methods and funds, and good men were engaged to do the work. The

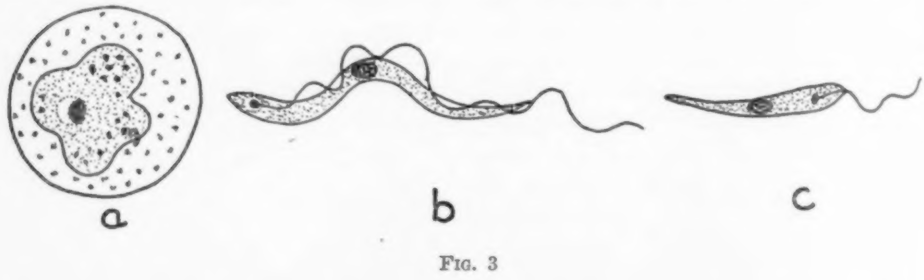

FIG. 3

inhabitants of many areas, especially those that are thinly populated, are, however, too poor to pay for properly carried out control measures. Malarial relapses complicate the situation, since usually patients are not actually cured by the drugs administered to them but retain enough parasites in their bodies to bring about a relapse when the resistance of the host becomes lowered. This often occurs in the spring just when mosquitoes become active, and the transmitters of the disease are thus provided with sources of infection.

Trypanosomes (Fig. 3b) are responsible for African sleeping sickness and Chagas' disease in South America. They do not live within the red corpuscles, as do the malarial parasites, but in the blood plasma. Large parts of Africa are uninhabitable because of the presence of trypanosomes. Wild game animals, such as antelope, serve as reservoirs of the trypanosomes of man in Africa from which the transmitting agents, the tsetse flies, may acquire their infections. Drugs such as Bayer 205, tryparsamide and Pasteur 309 are useful in the treatment of African sleeping sickness if administered in the earlier stages of the disease. Chagas' disease is transmitted by kissing-bugs of the genus *Triatoma* that live in the crevices of the mud huts of the natives in certain parts of South America. The armadillo has been found to serve as a reservoir for the species of trypanosome that causes this disease.

The leishmanias (Fig. 3c) cause kala-azar and oriental sore in certain regions of Asia and the Mediterranean region and uta in tropical America. The transmission of these diseases has not yet been determined, although the sand-fly probably is the intermediate host of the organism of oriental sore. This disease is of particular interest because one attack gives immunity, and since the sores usually occur on the face and leave scars, children are sometimes inoculated on some other part of the body by their parents so that they may escape disfigurement.

The following table presents a list of the twenty-five species of human protozoa.

PROTOZOA LIVING IN MAN

A. *Intestinal protozoa.*—These appear to be world wide in their distribution. They are located within the body as indicated.

Mouth	Percentage of population infected
1. *Endamoeba gingivalis* (ameba)	50
2. *Trichomonas buccalis* (flagellate)	10–30
Small Intestine	
3. *Giardia lamblia* (flagellate)	10
4. *Isospora hominis* (coccidium)	Rare
Large Intestine	
5. *Endamoeba histolytica* (ameba)	10
6. *Endamoeba coli* (ameba)	50
7. *Endolimax nana* (ameba)	25
8. *Iodamoeba williamsi* (ameba)	10
9. *Dientamoeba fragilis* (ameba)	Rare
10. *Trichomonas hominis* (flagellate)	5–20
11. *Chilomastix mesnili* (flagellate)	10
12. *Embadomonas intestinalis* (flagellate)	Rare
13. *Tricercomonas intestinalis* (flagellate)	Rare
14. *Balantidium coli* (cilate)	Rare
Vagina or Urinary Tract	
15. *Trichomonas vaginalis* (flagellate)	10–50 women

B. *Protozoa of muscle tissue.*—Only one apparently aberrant species is known to occur in man.

16. *Sarcocystis* sp. (sporozoon)	Rare

C. *Blood-inhabiting protozoa.*—These are restricted to certain rather definite areas as indicated.

	Geographical Distribution
Red Blood Corpuscles	
17. *Plasmodium vivax* (sporozoon) (organism of tertian malaria)	Tropical and subtropical countries
18. *Plasmodium malariae* (sporozoon) (organism of quartan malaria)	Tropical and subtropical countries
19. *Plasmodium falciparum* (sporozoon) (organism of estivo-autumnal malaria)	Tropical and subtropical countries
Blood Plasma	
20. *Trypanosoma gambiense* (flagellate) (organism of Gambian sleeping sickness)	Tropical Africa
21. *Trypanosoma rhodesiense* (flagellate) (organism of Rhodesian sleeping sickness)	Nyasaland, Rhodesia, etc.
22. *Trypanosoma cruzi* (flagellate) (organism of Chagas' disease)	Northern South America
Blood and Body Cells	
23. *Leishmania donovani* (flagellate) (organism of kala-azar)	Asia and Mediterranean regions
24. *Leishmania tropica* (flagellate) (organism of oriental sore)	Asia and Mediterranean regions
25. *Leishmania braziliensis* (flagellate) (organism of uta)	South and Central America

The protozoa of monkeys as well as of men have been carefully studied. The results are of considerable biological interest since in most cases it has been impossible to distinguish the parasitic protozoa of man from those of monkeys. The monkey protozoa have been given distinct scientific names, but the foremost protozoologists at the present time are unable to distinguish them from the protozoa of man. Original observations by the writer and a review of the literature indicate that twenty of the protozoa of man also occur in monkeys.[1] The five species that have not been recorded from monkeys are as follows: the three species of *Leishmania;* the coccidium, *Isospora hominis,* and the sporozoon, *Sarcocystis.* It is interesting to note that *Isospora* and *Sarcocystis* are very rare in man—a fact which suggests that they may eventually be discovered in monkeys. There is no obvious explanation of the absence of the leishmanias in monkeys since it is possible to infect monkeys with them under laboratory conditions. Protozoa belonging to two genera and four species have been found in monkeys but not in man; these are the intestinal ciliates *Troglodytella abrassati, T. a. acuminata* and *T. gorillae,* and the blood-inhabiting sporozoon, *Babesia pitheci.*

Other lower animals, such as cats, dogs, rats, cattle, birds, lizards, frogs, etc., are parasitized by both intestinal and blood-inhabiting protozoa, many of which belong to the same genera as those in man; but, almost without exception, it is possible for one familiar with these organisms to distinguish them morphologically as specially different from human protozoa. For example, the following species belonging to the same genera occur in rats and man:

Rat	Man
Giardia muris	*Giardia lamblia*
Trichomonas muris	*Trichomonas hominis*
Endamoeba muris	*Endamoeba histolytica*
Trypanosoma lewisi	*Trypanosoma gambiense*

A protozoologist can identify these species from these two hosts on the basis of difference in structure without knowing from which host they were obtained.

These observations have an important bearing on the theory of organic evolu-

[1] Robert W. Hegner and William H. Taliaferro, "Human Protozoology," 1924; C. M. Wenyon, "Protozoology," 1924; current literature referred to in *Quarterly Cumulative Index Medicus.*

tion, since it has been found that animals that are closely related are infected with similar parasites and the closer their kinship the more nearly alike are their parasites. The remarkable situation noted above with respect to the protozoan parasites of monkeys and man indicate that a very close relationship exists between these types of hosts. It seems very probable that the protozoa that are now found in man and monkey are direct descendants of protozoa that lived in the ancestors of these hosts, and that man and monkey had the same common ancestry. Thus the study of protozoan parasites has furnished us with another important type of evidence in favor of the organic evolution of man from a monkey-like ancestor.

To summarize, human beings are parasitized by about twenty-five different species of protozoa. Some of these, the intestinal protozoa, appear to be world wide in their distribution; others, the blood-inhabiting protozoa, are restricted to certain geographical areas. Fortunately, most of these parasites are either harmless, of very little clinical importance or not of frequent occurrence. The most dangerous species are the malarial parasites which occur generally throughout tropical and subtropical countries and are the cause of the most important of all tropical diseases, the trypanosomes that are responsible for sleeping sickness in certain parts of Africa and of Chagas' disease in South America, the leishmanias that cause kala-azar and oriental sore in parts of Asia and the Mediterranean region and uta in South and Central America, and *Endamoeba histolytica* which occurs throughout the world but brings about amebic dysentery usually only in the tropics. Drugs have been discovered that are effective against most of these parasites, and infected persons can be cured or at least relieved of their symptoms if treatment is begun in the early stages of the disease. The high percentage of the general population infected with intestinal protozoa indicates that our food and drink must be highly contaminated and that our sanitation is not as effective as it should be. A comparison of the protozoa living in monkeys and man reveals the fact that twenty of the twenty-five species recorded from man also occur in monkeys. This indicates a close genetic relationship between monkeys and man and suggests that these protozoa have accompanied monkeys and man in their evolution from a common ancestor.

RECENT STUDIES OF HAIR STRUCTURE RELATIONSHIPS

By Professor LEON AUGUSTUS HAUSMAN

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HAIR, characteristic of the *Mammalia*, and found in no other animal group, present in all species though but sparsely developed in some, occurring in all gradations of development from a mat of fine soft fur to a panoply of coarse heavy spines, is a product of the outermost layer of the skin, the epidermis, and no matter how different it may appear in its apparent forms is structurally a remarkably homogeneous animal tissue. Each hair shaft arises from the proliferation of the cells of the bulbous upward growth in the base of a flask-shaped depression in this epidermal layer, the bulbous growth being known as the papilla of the hair (Fig. 1, A). The rapid multiplication of the cells upon and around this papilla results in the gradual extrusion of these proliferated cells toward the mouth of the follicle at the level of the epidermis. These cells form both the layers of the root sheath of the hair and the four structural elements of the hair shaft. The hair shaft is now pushed out of the mouth of the follicle, with its four structural elements established. These are (Fig. 1, B): (1) the medulla, or medullary column, made up of variously disposed chambers sometimes separated, sometimes coalesced, and termed popularly the pith of the hair; (2) the cortex, surrounding the medulla, composed of elongated, fusiform, often much shrunken cells (sometimes referred to as hair spindles) fused together into a rigid, almost homogeneous, hyaline, transparent mass; (3)

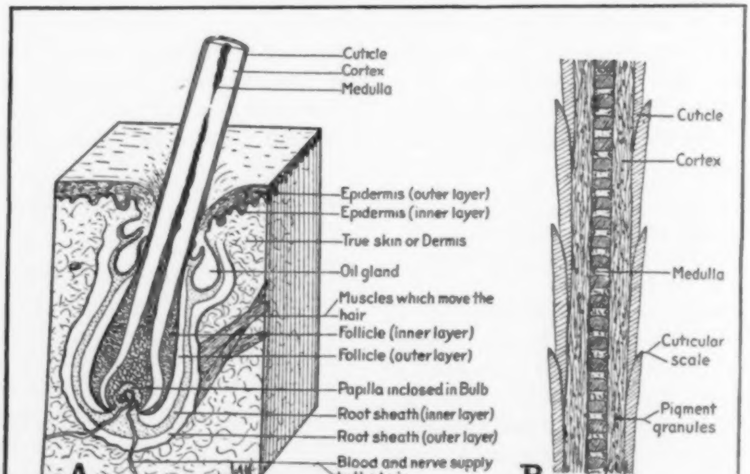


FIG. 1. A DIAGRAMMATIC LONGITUDINAL SECTION

A. THROUGH A MAMMALIAN HAIR OF THE BROKEN-MEDULLA TYPE, AND ITS TISSUES OF ORIGIN AND ATTENDANCE. *B.* A SIMILAR SECTION THROUGH A HAIR-SHAFT OF THE DISCONTINUOUS-MEDULLA TYPE.

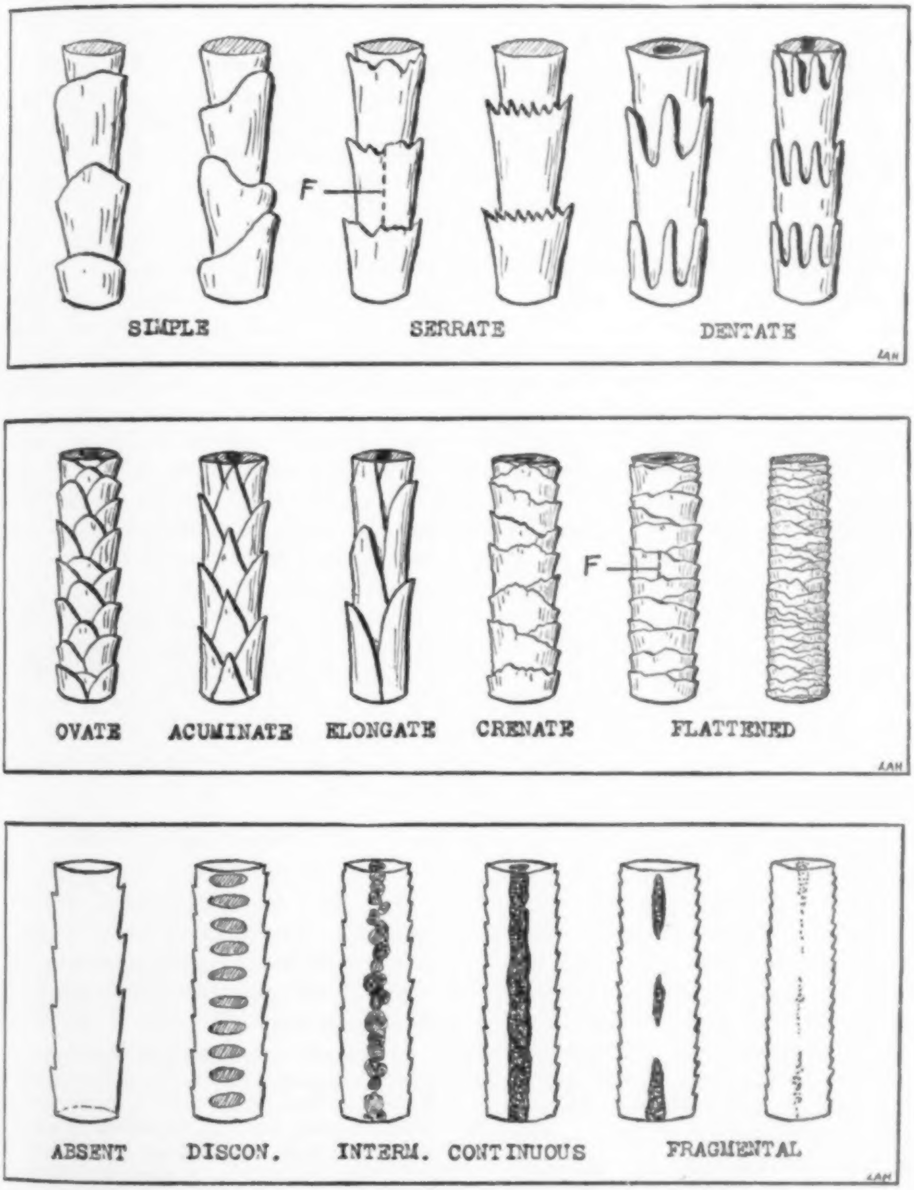


FIG. 2. TYPE FORMS OF CUTICULAR SCALES AND MEDULLAS OF MAMMALIAN HAIR. *Above:* CORONAL SCALES; *Center:* IMBRICATE SCALES; *Below:* MEDULLA TYPES.

the pigment granules, to which the color of the hair is primarily due (though in some cases this pigmentary substance is diffuse), located in and among the cells of the cortex, and to a less extent in the medullary column, and (4) the cuticle or outermost investiture of the hair shaft, composed of thin, horny, transparent plates of keratized protoplasm, of a multitude of pleasing forms and relationships.

After the hair shaft has made its appearance above the level of the epidermis and its various parts are cornified (keratized) and hardened, it may be termed a mature hair shaft. Thereafter there is but little change in the relationships of its various parts, though the forms of its various structural elements undergo some modifications (differing with different species of mammals) as the shaft increases in length. As far as any physiological connection with the epidermal layer which gave it birth is concerned, the hair shaft is a dead structure. No blood or nerve supply is carried up into its shaft, these ending in the papilla, and the hair shaft is increased in length by additions to its base from the proliferations of the cells of the papilla. It seems impossible, therefore, that hair should turn white overnight (as is often stated), as the pigments once pushed out inside the hair shaft have no vital connection with the blood supply. Whitening of hair overnight (or within a very few days) has often been claimed, but not proved. Apparently the only way in which hair can turn white is through a failure of the cells of the papilla to produce their natural pigmentary secretions while the hair shaft is being formed. As the new material of the shaft is gradually pushed out, it emerges as a colorless (*i.e.*, in the case of humans, white) hair. But this process would produce a completely white hair, that is, white from base to tip, only after a growth of some months. This is elsewhere discussed in connection with the life of a single hair shaft.

In this paper, the discussion of the forms and relationships of the four structural elements of the hair shaft (unless otherwise noted) concerns itself with the condition of these elements as found midway between the distal and proximal ends of representative mature hair shafts.[1]

In discussing mammalian hair it is convenient to assign the mammals to two groups, the *Infrahominidae* (mammals below man) and the *Hominidae* (man himself). With respect to the scalation of mammal hairs in general, the scales fall naturally into two form-groups: the coronal scales and the imbricate scales. The coronal scales (Fig. 2, above) completely encircle the cortical cylinder of the hair shaft and may be likened to glass tumblers, without bottoms, set one within another, their free ectal edges sculptured in various forms. The imbricate scales (Fig. 2, center) do not individually encircle the cortical cylinder, but are arranged like the scales of a fish or the shingles on a roof, and their free distal edges are likewise etched into different shapes.

CUTICULAR SCALES OF THE *Infrahominidae*

One of the most interesting and surprising relationships which came to be appreciated as the cuticular scales of the infrahominid mammals were studied was that, in general, the size of the scales

[1] All figures, unless otherwise described, show these structures as they occur in this region of the shaft. The figures of hair shafts are not drawn to scale, since the diameters of some of the shafts shown are as great as 150 microns, and others as little as 6 microns. The practice here has been to draw all shafts *above* 30 microns as if they were of one diameter, and all shafts *below* this as if they were of one smaller diameter. All drawings are original delineations, or micrographs, made directly from the microscope, the size relationships being determined with the ocular micrometer.

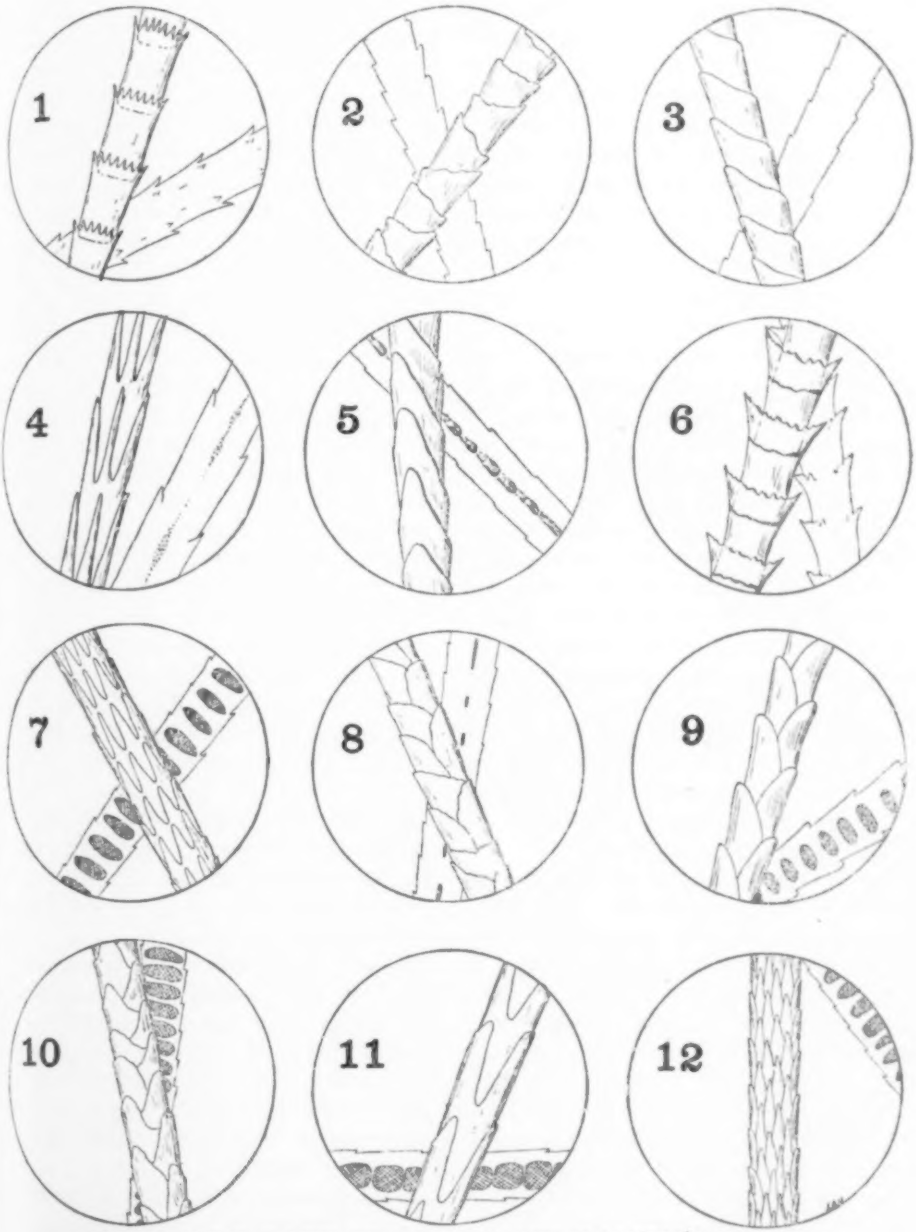


FIG. 3. SOME FORMS OF CORONAL AND IMBRICATE SCALES AND MEDULLAS OF MAMMALIAN HAIR SHAFTS. ALL SHAFTS DRAWN AS THOUGH OF THE SAME DIAMETER, THOUGH THEY RANGE FROM 6.80 MICRONS (NO. 1, INTERMEDIATE BAT) TO 27.20 MICRONS (NO. 8, THREE-TOED SLOTH). 1. INTERMEDIATE BAT (*Mormops intermedia*). 2. PHYLLOPS (*Phyllops falcatus*). 3. RED BAT (*Lasiurus borealis*). 4. EUROPEAN OTTER (*Lutra vulgaris*). 5. EUROPEAN BEAVER (*Castor fiber*). 6. WRINKLED LIPPED BAT (*Nyctinomus bocagei*). 7. CALIFORNIA SEWELLEL (*Aplodontia californica*). 8. THREE-TOED SLOTH (*Bradypus tridactylus*). 9. GIANT GOLDEN MOLE (*Chrysochloris trevelyani*). 10. STRAND MOLE RAT (*Bathyergus maritimus*). 11. MINK (*Mustela vison*). 12. BAIRD'S SHREW (*Sorex bairdi*).

(*i.e.*, their antero-posterior width) and their forms varied together in a constant way. Moreover, the size (and hence also the forms) of the scales bore a relationship, not to the species of mammal bearing the hair, but to the diameter of the hair shaft bearing the scales. Thus it may be said that, knowing the diameter of the hair shaft, one can predict what sort of scales will be found upon it. In the finest and softest hairs (*i.e.*, those of least shaft diameter), one encounters only the coronal type of scales. These scales occur in a great variety of forms, which fall into the following elemental types (Fig. 2, above): (1) simple, (2) serrate, (3) dentate. Modifications of these types occur in very interesting relationships, some with respect to the diameter of the hair (minute modifications of the contours of the free ectal edges of the scales which do not disturb the classification just mentioned); some with respect to their positions on the hair shaft (whether proximal, distal or medial); some apparently with respect to the vigor or languor of the papillal cells; some with respect to the species, in a way not yet understood, and now the subject of study in the writer's laboratory. In Fig. 3, 1 to 7, are shown some typical coronal scale forms. It is interesting to note that the bats, whose habits are more like the birds than are those of any other vertebrate and which have need of a light body covering which shall give at once the maximum of heat-insulating qualities with the minimum of weight, have developed, as a group, a hair which in its superficial configuration and in its actual effect *en masse* upon the body is, of all vertebrate integumental structures, most like a feather.

Upon the shafts of hairs coarser than those of the bats (those roughly above 8.50 microns in diameter) one finds almost exclusively the imbricate type of scales. These may be grouped into five appreciably distinct groups (Fig. 2, center): (1) ovate, (2) acuminate, (3) elongate, (4) crenate and (5) flattened. Some representative modifications of these five types may be seen in Fig. 3, 8 to 12, and Fig. 4, entire figure.

In Fig. 5 is shown graphically the relationship existing between the scale types and the shaft diameters of infra-hominid mammals. The fractional numbers in decimal along the curve are the scale indices, which are the expressions of the ratio of the size of the scale to the diameter of the hair shaft. By size of scale is meant the length of the free proximo-distal diameter of the scale, as shown by the letter F in Fig. 2, above and center.[2] The smaller the hair, then, the larger the scales, and their forms follow. In discussing this graph, it must be remembered that the associations represented deal with large groups and averages. The coincidence of scale form and scale size is as though the hair shafts, increasing in diameter, pull out and flatten the cuticular scales proximo-distally and, except in the case of some of the hairs of greatest diameter, smooth out their distal edges. These differences in form are the results of the differences in the activities of the cells of the hair papilla, plus also, it is believed, some differences in the gradual drying out of the hair shaft, plus also the effects of wear on the free ectal edges of the scales, particularly at the tips of the shaft. The activities of the papillal cells produce differences both at the tip and the base of the hair shaft, *i.e.*, when these cells begin, and close, their mitosis. Along the middle of the shaft the scales are fairly uniform in shape and relationships. Differences in the organization of the medullary column and pigmentation

[2] Where the diameter of the hair shaft = D and the proximodistal diameter of the free surface of the cuticular scale = F and the scale index = I, the equation is $\frac{F}{D} = I$.

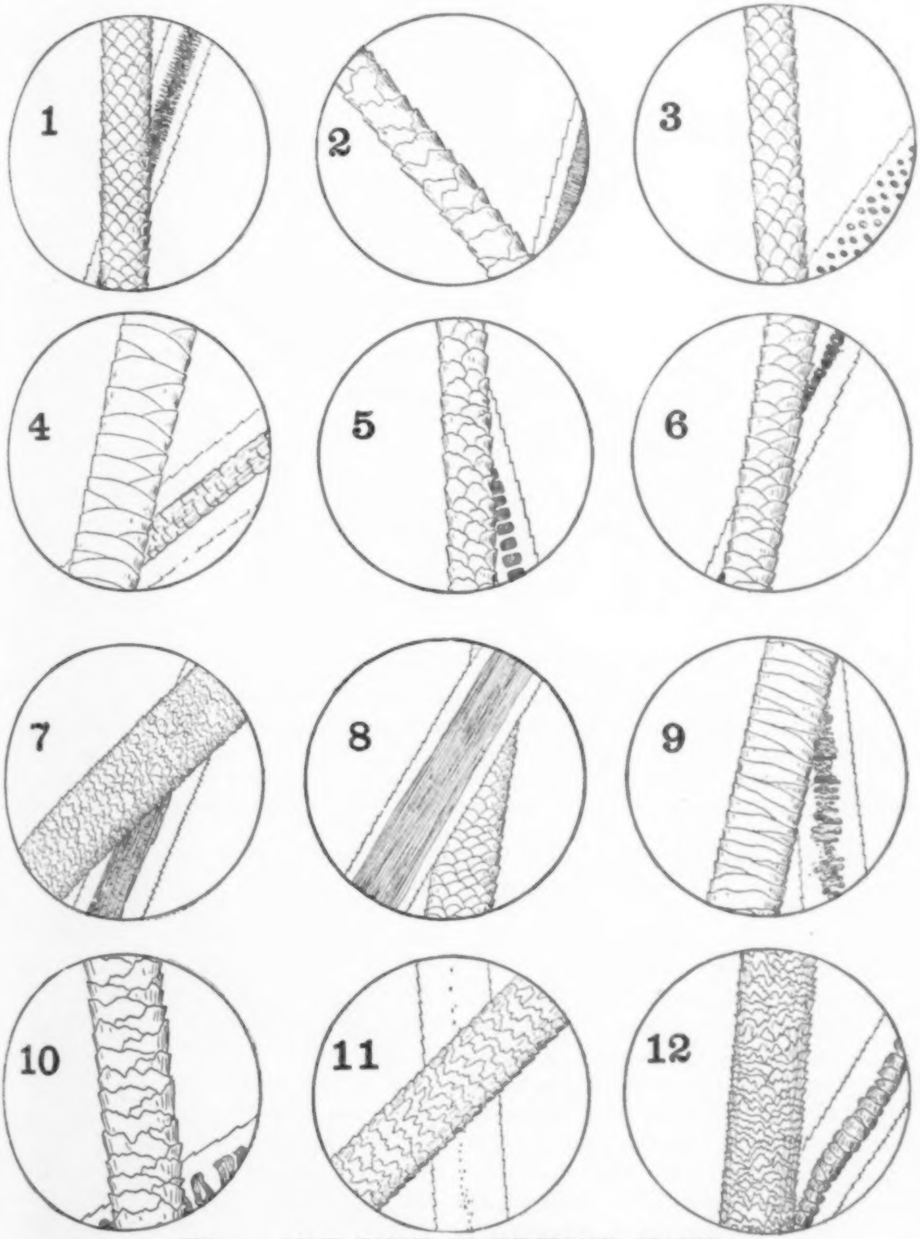


FIG. 4. SOME FORMS OF IMBRICATE SCALES

AND MEDULLAS OF MAMMALIAN HAIR SHAFTS. SHAFTS ARE DRAWN AS THOUGH THEY WERE OF TWO DIAMETERS: THOSE ABOVE 30 MICRONS OF ONE SIZE, AND THOSE BELOW 30 MICRONS OF ANOTHER. THE SHAFTS HERE SHOWN RANGE IN DIAMETER FROM 20.00 MICRONS (NO. 5; TANA) TO 153.00 MICRONS (NO. 9, SEA LION). 1. THIBETAN SUN BEAR (*Helarctos thibetianus*). 2. PATAS MONKEY (*Cercopithecus patas*). 3. POCKET RAT (*Thomomys nevadensis*). 4. GREAT ANTEATER (*Myrmecophaga tridactyla*). 5. TANA (*Tana chrysura*). 6. SAGOUIN (*Hapale penicillata*). 7. PERCHERON MARE. 8. TRUE'S WHITE TAILED DEER (*Odocoileus truei*). 9. NORTHERN SEA LION (*Eumentopias stelleri*). 10. TITI (*Callithrix jacchus*). 11. PEBA ARMADILLO (*Tatu novemcincta*). 12. HEDGEHOG (*Erinaceus hindei*).

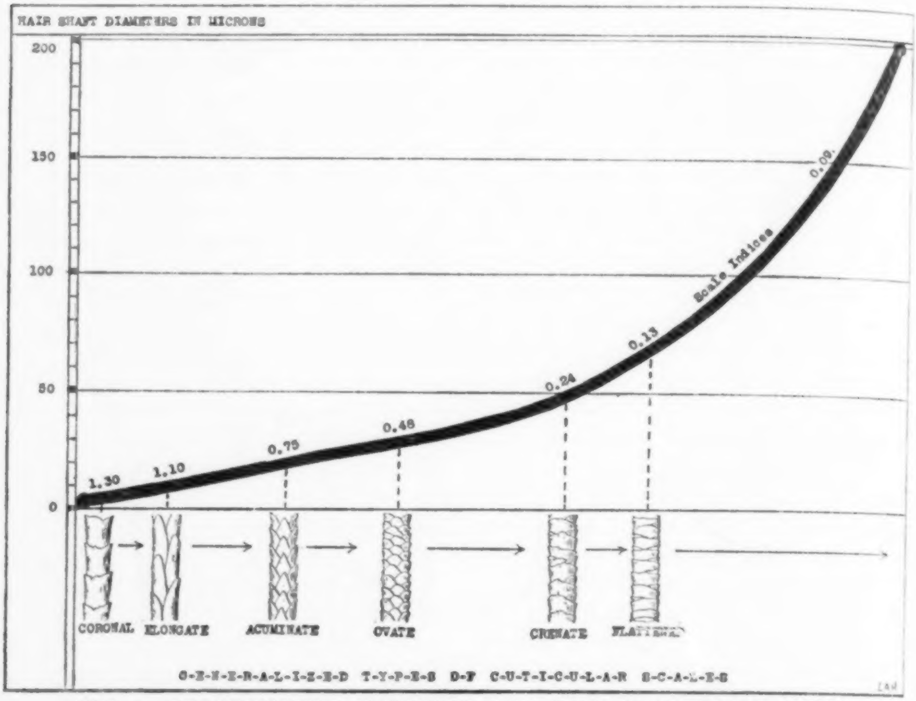


FIG. 5. RELATIONSHIP BETWEEN THE CUTICULAR SCALE FORM AND THE HAIR-SHAFT DIAMETERS OF INFRAHOMINID HAIRS, AS SHOWN BY THE STUDY OF 217 SAMPLES OF SUCH HAIRS, FROM SPECIES REPRESENTING ALL THE EXISTING ORDERS OF MAMMALS EXCEPT THE *Cetacea* (WHALES AND THEIR KIN). THE GENERAL REGIONS OF THE OCCURRENCE OF THE SCALE FORMS ARE SHOWN ALONG THE ABCISSA, THE AVERAGE SCALE INDICES ALONG THE CURVE.

are also to be seen along the length of the hair shafts. The lifetime of a papilla (synonymous with the lifetime of a hair), that is to say, the time during which the proliferation of its cells (and the consequent formation of the hair shaft) is continuous, is said to be, for the human head hair, between five and six months. When a hair shaft is about to be shed, the proliferation of its papillal cells ceases; the papilla itself gradually atrophies, and then becomes cornified. The hair shaft, pulled away at its base from the papilla, is pushed outward toward the mouth of the follicle by the continued multiplication of the cells of the root sheath, and finally drops out of the follicle. Or it may be pushed out by the growth of a new shaft, from the renewed activity of new cells upon a rejuvenated papilla. In some species of

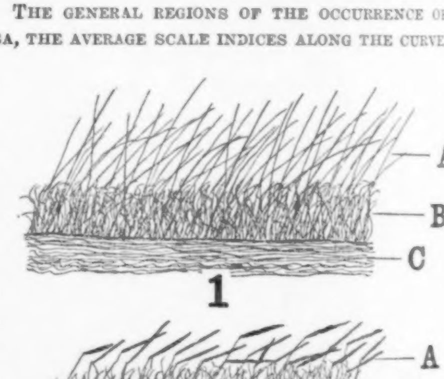


FIG. 6. RELATIONSHIP OF PROTECTIVE HAIR TO FUR

1. IN A TYPICAL MAMMAL. 2. IN THE DUCKBILL (*Ornithorhynchus anatinus*). *A.* PROTECTIVE (OVER) HAIR. *B.* FUR (UNDER) HAIR. *C.* SKIN.

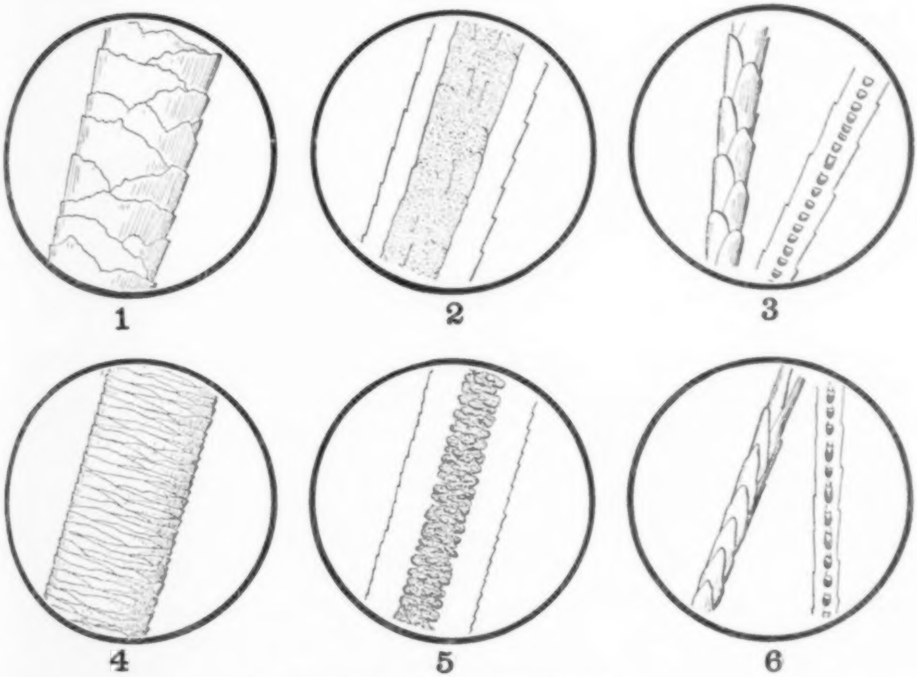


FIG. 7. STRUCTURAL DIFFERENCES

BETWEEN THE PROTECTIVE HAIRS AND THE FUR HAIRS, AS ILLUSTRATED IN TWO COMMON SPECIES OF MAMMALS. *Above*, THE COMMON SKUNK (*Mephitis mephitis*). 1. SCALATION OF THE PROTECTIVE HAIR. 2. MEDULLATION OF THE PROTECTIVE HAIR. 3. SCALATION (LEFT) AND MEDULLATION (RIGHT) OF THE FUR HAIR. *Below*, THE EUROPEAN BEAVER (*Castor fiber*). 4. SCALATION OF THE PROTECTIVE HAIR. 5. MEDULLATION OF THE PROTECTIVE HAIR. 6. SCALATION (LEFT) AND MEDULLATION (RIGHT) OF THE FUR HAIR. IN THIS INSTANCE THE HAIR SHAFTS IN EACH ROW ARE DRAWN TO SCALE.

mammals this renewed and seasonal atrophy of the papilla gives rise to the familiar phenomenon of moulting.

Cuticular scales may vary in a slight way with the shape of the cross-section of the hair shafts. Shafts are, in general, circular or elliptical in cross-section and do not vary from this much between base and tip, but there are instances of hair shafts with broad, flattened, spear-head-like tips, as, for example, in the over-hairs of the duckbill (*Ornithorhynchus anatinus*),[3] Fig. 6, 2A, and other aquatic forms. In this case, the cuticular scales on the broadened tip portion of the shaft are different in form from those on the smaller middle and basal portions of the shaft.

Pathological conditions within the follicle give rise to abnormal hair forms, as in monolethrix, trichorrhexis and others. Asymmetry in the development of medulla, cuticle and pigment depositions has been found by the writer to be fairly common in human head hair.

In many species of mammals two sorts of hair are produced; a long, coarse, over-hair, or protective hair, and a shorter, softer, under-hair, or fur hair (Fig. 6). The forms of the scales of these two sorts of hair follow the law of

[3] L. A. Hausman, "A Micrological Investigation of the Hair Structure of the *Monotremata*," *Am. Jour. Anat.*, 27: 463, 1920.

1 2 3

FIG. 8. HOW CLIPPING WEAKENS FUR

1. TIP OF THE SHAFT OF AN UNCLIPPED HAIR OF RABBIT OR HARE. 2. CUT END OF A CLIPPED RABBIT HAIR SHAFT. NOTE HOW THE CLIPPING AT ONCE ROBS THE END OF ITS PROTECTIVE COVERING OF CUTICULAR SCALES AND EXPOSES THE END TO FRAYING OUT. 3. THE USE OF THE COMPARISON OCULAR IN IDENTIFYING FUR HAIRS. THE HAIR SHAFT OF A GENUINE AMERICAN OTTER ABOVE, AND THE NUTRIA OR COYPU RAT BELOW, SOMETIMES USED AS A SUBSTITUTE. NOTE HOW THE GRANULATION AND MEDULLATION TELL THE STORY AND AFFORD A CERTAIN CRITERION FOR IDENTIFICATION. NOTE ALSO THE DIFFERENCES IN SHAFT DIAMETERS.

shaft-diameter association just explained (Fig. 7).

In spite of the fact that, in general, the forms of the cuticular scales bear relationship to shaft diameter rather than to species, there are sometimes present minute apparently specific differences in the sculpturings of the free ectal edges of the scales. These are not yet fully understood or classified, nor is it yet certain that they are specific differences, and one part of the work in the writer's laboratory is being focused upon this aspect of the problem of hair structure relationships. Enough, however, is known about the diagnostic value of some of these possibly specific scale-configuration criteria to show that it is possible to identify the species-source of a hair sample from the cuticular scales alone. Where this criterion fails, we still may have recourse to the diagnostic characters offered by the structure of the medulla and the pigment bodies, of which we shall speak later.

The cuticular scales form a protective covering around the cortex of the hair shaft which prevents its splintering out and wearing away. It is for this reason that, with respect to furs used as garments, clipping greatly weakens the individual hairs against wear, and results

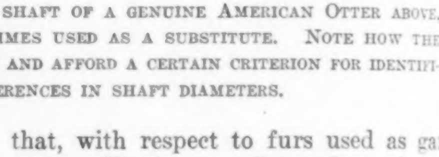


FIG. 9. RELATIONSHIPS BETWEEN THE SIZES

(*i.e.*, PROXIMO-DISTAL DIAMETERS OF FREE SURFACES) OF THE CUTICULAR SCALES, AND THE DIAMETERS OF THE HAIR SHAFTS AS SHOWN BY A STUDY OF 122 SAMPLES OF HUMAN HEAD HAIRS, REPRESENTING ALL THE EXISTING RACES OF MANKIND.

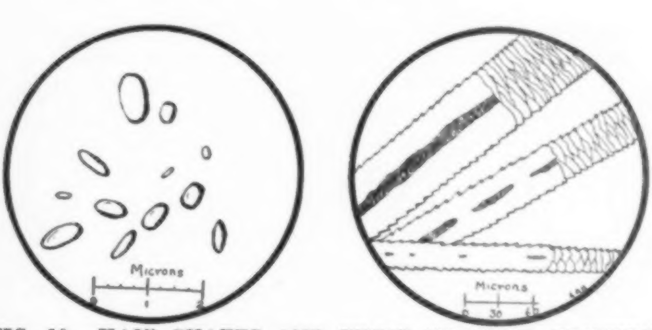


FIG. 10. HAIR SHAFTS AND THEIR PIGMENT GRANULES

Left: PIGMENT GRANULES FROM THE CORTEX OF HUMAN HEAD HAIR SHAFT, TO SHOW THE NORMAL VARIATION IN SIZE AND SHAPE. *Right:* THREE HAIR SHAFTS FROM THE RIGHT TEMPORAL REGION OF THE SAME HEAD, SHOWING THE VARIATION WHICH MAY OCCUR. THE BASAL PORTIONS OF THE SHAFTS HAVE BEEN CLEARED TO SHOW THE MEDULLAS.

in the production of a less durable fur than would have been the case had the hairs been left with their natural tips. In Fig. 8 is shown the appearance of clipped and unclipped rabbit hairs. Whenever a hair shaft is clipped, it presents, under the microscope, the appearance shown in Fig 8, 2. The friable cortex and medulla elements are left to fray out without the natural protection of the hard, smooth investiture of the cuticular scales, as shown in the natural hair tip (Fig. 8, 1). In hair shafts with smaller medullary columns than those of the rabbit or hare, the rate of wear of the clipped fur is relatively less, but is still more rapid than that of the same fur with its natural tips left intact.[4] This difference in the rate of wear of furs with clipped and unclipped ends has been accurately measured by an apparatus termed the tribometer (wear measurer) devised and used by the writer some years ago.[5]

CUTICULAR SCALES OF THE *Hominidae*

The cuticular scales of human head hair are of the flattened type (Fig. 2, center), and vary in size with the diameter of the hair shaft as do the scales of the *Infrahominidae*. A graphic expression of this variability is shown in Fig. 9. As the hair shaft becomes smaller, the scales become larger, and tend toward the ovate forms. This is important, for it means that scale forms are, therefore, unrelated to race.[6] It has been found that the diameters of hair shafts from the same head may vary quite considerably, not only at different ages, but contemporaneously. This is accompanied by the characteristic variation in the scales (Fig. 10, right). And Wynkoop[7] has shown recently that the scales (as well as the medullas) bear relationship not to the age of the individual, but to the diameter of the hair shaft in which they occur. No differences in this flattened type of scale analogous to the supposititious specific differences noticed in the hairs of the *Infrahominidae* have been found. This is interpreted as being the cuticular scales indication that mankind is a single species.

[4] Moreover, a hair robbed of its flexible tip becomes stiffer and hence more likely to break under the strain of to and fro rubbing.

[5] L. A. Hausman, "Measuring the Durability of Furs," *Sci. Am. Monthly*, September, 1921 (published formerly by the *Scientific American* publishing company, but now discontinued).

[6] L. A. Hausman, "A Comparative Racial Study of the Structural Elements of Human Head Hair," *Am. Nat.*, 59: 529, November–December, 1925.

[7] E. M. Wynkoop, "A Study of the Age Correlations of the Cuticular Scales, Medullas and Shaft Diameters of Human Head Hair," *Am. Jour. Phys. Anthrop.*, 13: 177, No. 2, July–September, 1929.

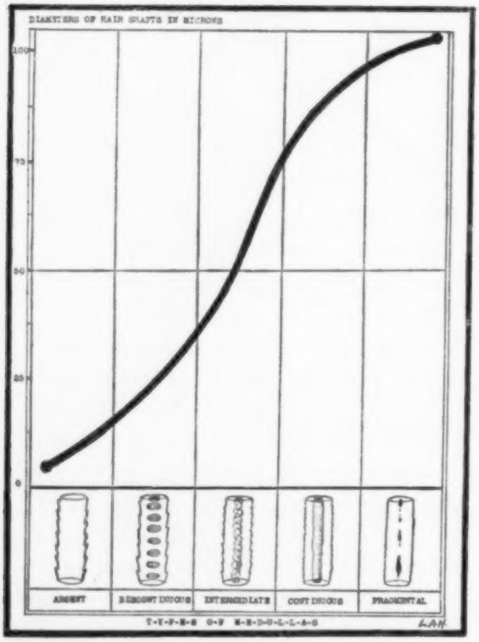


FIG. 11. GRAPHIC REPRESENTATION OF THE PRINCIPLE

THAT THE MEDULLA FORM OF THE HAIR SHAFT VARIES WITH THE DIAMETER OF THE SHAFT, AS SHOWN BY 197 SPECIES OF MAMMALS BELOW THE *Hominidae*. ALL THE EXISTING ORDERS OF *Mammalia* ARE REPRESENTED BY THE HAIR SAMPLES USED IN THIS STUDY, EXCEPT THE *Cetacea* (WHALES AND THEIR KIN).

MEDULLAS OF THE *Infrahominidae*

The medullas of the hairs of the infrahominid mammals fall into five classes (Fig. 2, below): (1) absent, (2) discontinuous, (3) intermediate, (4) continuous and (5) fragmental. The discontinuous medulla is a series of isolated chambers or cells, of regular form and placentation, made up of variously shrunken and cornified elements and sometimes containing pigmentary materials. The intermediate and continuous medullas seem to represent progressive coalescence stages of the first type, and the fragmental medulla the break-up and gradual disappearance of the fully fused, continuous type.

Many secondary specific variations in medulla form occur in infrahominid hairs, but with respect to the categories just listed, and with regularity, the relationships of the medulla *types* are not with species, but with the diameters of the hair shafts in which the medullas occur. The curve in Fig. 11 is intended to make this relationship clear. Thus among the bats one finds few medullas, most of the species being without this element. Among the smaller insectivores and rodents (bearing soft, fine hair) medullas of the discontinuous and intermediate types are prevalent, especially the former, while in the mammals bearing coarser hair (as the ungulates, primates, etc.) the continuous and fragmental medullas largely occur. Fre-

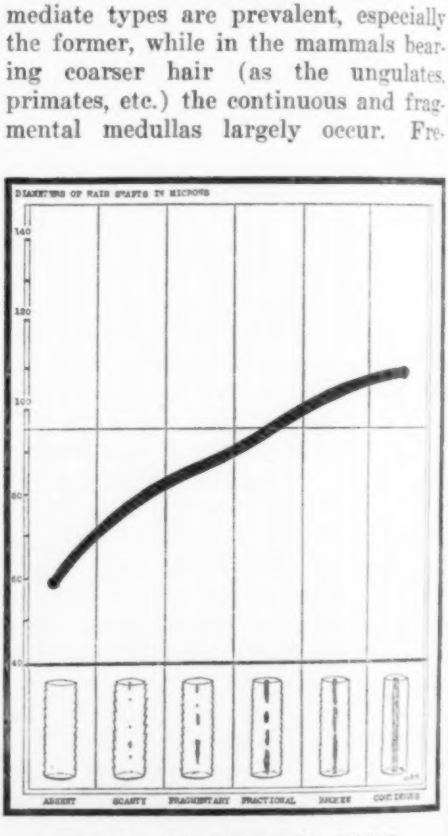


FIG. 12. HUMAN HEAD HAIRS

RELATIONSHIPS BETWEEN THE MEDULLA FORM AND THE HAIR-SHAFT DIAMETERS OF HUMAN HEAD HAIRS, AS SHOWN BY A STUDY OF 122 SPECIMENS OF SUCH HAIRS FROM INDIVIDUALS REPRESENTING ALL THE EXISTING RACES OF MANKIND.

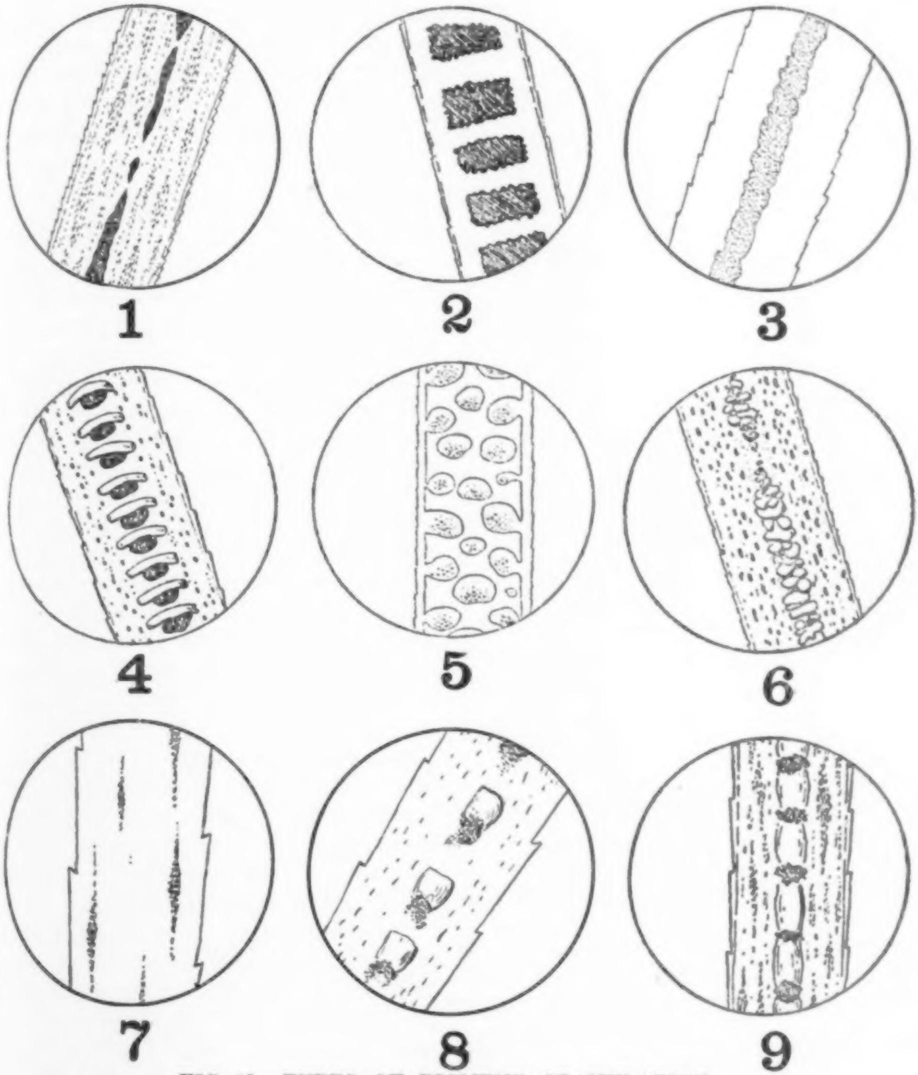


FIG. 13. TYPES OF PIGMENT GRANULATION

IN THE HAIRS OF VARIOUS INFRAHOMINID MAMMALS, COMPARED WITH THAT OF MAN. 1. HEAD HAIR OF PRE-COLUMBIAN PERUVIAN MUMMY, TYPICAL OF THE GRANULATION IN A FUSCOUS BROWN HAIR. THE MEDULLA APPEARS BLACK BY TRANSMITTED LIGHT, BUT CONTAINS NO PIGMENT. 2. DARK GRAY HAIR OF THE SEWELLEL (*Aplodontia californica*), WITH THE PIGMENT MASSES IN THE MEDULLA. 3. PURE WHITE HAIR OF THE POLAR BEAR (*Thalarctos maritimus*), CONTAINING NO PIGMENT. 4. GRAYISH BROWN HAIR OF THE BLARINA (*Blarina brevicauda*), WITH PIGMENT MASSES IN THE MEDULLA AND GRANULES IN THE CORTEX. 5. GRAY HAIR OF THE SENNET KANGAROO RAT (*Perodipus sennetti*), WITH PIGMENT GRANULES IN MEDULLARY POCKETS. 6. DEEP-YELLOW HAIR FROM THE WRISTS OF THE SQUIRREL MONKEY (*Chrysothrix sciurea*), WITH THE PIGMENT IN THE FORM OF ELONGATED GRANULES IN THE CORTEX. 7. BROWN HAIR OF THE BROWN BAT (*Vespertilio fuscus*), THE PIGMENT IN THE FORM OF GRANULES ARRANGED IN PATTERNS SIMILAR TO THOSE IN HUMAN HAIRS. 8. BROWN HAIR OF THE NEW YORK WEASEL (*Putorius noveboracensis*), WITH ITS PIGMENT IN MEDULLARY GRANULAR MASSES AND CORTICAL GRANULES. 9. DARK BROWN, ALMOST BLACK HAIR OF THE BLACK BEAR (*Ursus americanus*), THE PIGMENT IN THE FORM OF GRANULAR MEDULLARY MASSES AND CORTICAL GRANULES ARRANGED IN OVAL PATTERNS AS IN HUMANS.

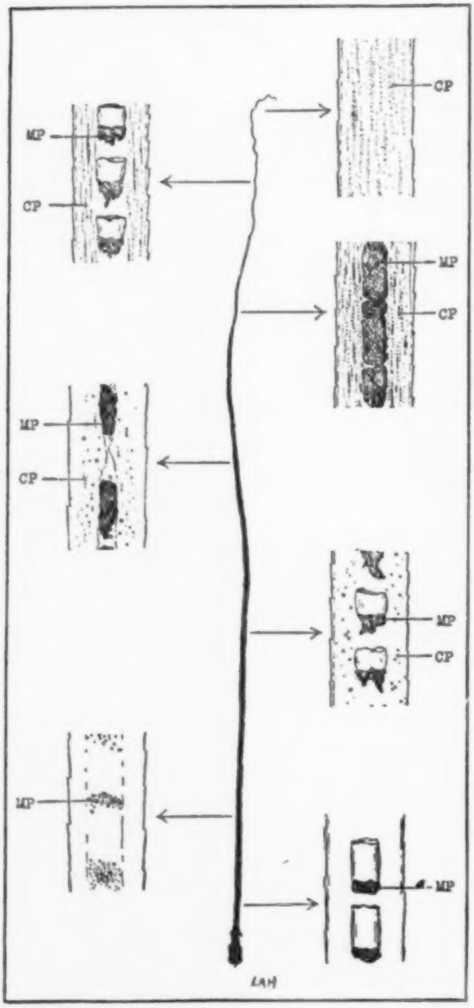


FIG. 14. CHANGES IN THE PIGMENTATION CHARACTERS

FROM THE BASE TO THE TIP OF A SINGLE FUR, OR UNDER HAIR FROM THE MUSKRAT (*Fiber sibethecus*), OCCURRING IN THE REGION OF THE MEDULLARY COLUMN. NOTE THAT, IN THIS HAIR SHAFT, THE PIGMENT MASSES AT THE BASE OF THE SHAFT WERE CONFINED TO THE MEDULLA; THOSE AT THE TIP WERE IN THE FORM OF GRANULES IN THE CORTEX, WHEREAS AT ALL OTHER POINTS (EXCEPT NO. 2) THE HAIR SHAFT OWED ITS COLOR TO A COMBINATION OF THESE TWO TYPES OF PIGMENTATION. *MP*—MEDULLARY PIGMENT; *CP*—CORTICAL PIGMENT.

quently one encounters very large, coarse hairs in which the medulla is lacking altogether, having apparently arrived at this state through the disappearance of a medulla of the fragmental type.

MEDULLAS OF THE *Hominidae*

Medullas of human head hair have been regarded as a separate subtype of the continuous type established for mammal hair in general, and are grouped as follows (Fig. 12): (1) absent, (2) scanty, (3) fragmentary, (4) fractional, (5) broken and (6) continuous. Here again the relationships of these medulla types is not with age[7] or with race,[6] but with the diameters of the hair shafts, as indicated by the graph in Fig. 12. The coarser the hair the more nearly continuous and solid is the medullary column, though many variations may occur. And since hair shafts from the same head may vary in diameter, the medullas which they show may vary correspondingly. It is only when one has examined a large series of hair samples from individuals representing many races and ages that the true status of the distribution and relationships of the microscopic elements of hair shaft structures becomes appreciable.

It is interesting from the standpoint of what has been said regarding the close parallelism between both scale and medulla form and the diameter of the hair shaft to note what a comparison of the two curves (Figs. 11 and 12) reveals: (1) that in both hominids and infrahominids the hair shafts of about the same diameter (in the neighborhood of 80 to 100 microns) bear very nearly the same types of medullas, and (2) that the hominid hairs do not show the discontinuous or intermediate types exhibited by the hairs of the infrahominid species. No matter how small the diameters of hominid hairs, the discontinuous and intermediate types of medullas

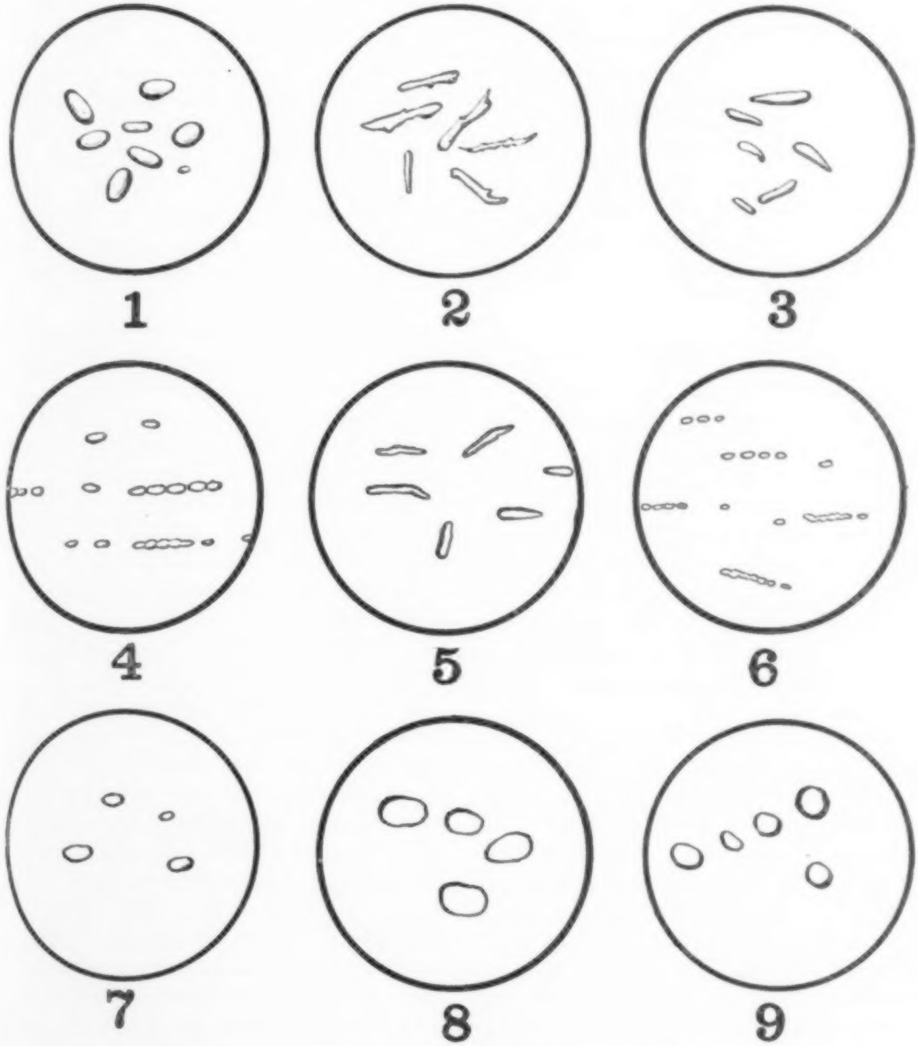


FIG. 15. VARIOUS FORMS OF PIGMENT GRANULES

OCCURRING IN THE CORTICES OF MAMMALIAN HAIR SHAFTS: 1. HEAD HAIR OF MAN (APACHE INDIAN), BLACK. 2. WRIST HAIR OF THE SQUIRREL MONKEY (*Chrysothrix sciurea*), YELLOW. 3. FUR HAIR OF THE AMERICAN OTTER (*Lutra canadensis*), BROWN. 4. FUR HAIR OF THE SEA OTTER (*Latax lutris*), BROWN. 5. FUR HAIR OF THE BLACK BEAR (*Ursus americanus*), BLACK. 6. HAIR OF THE BROWN RAT (*Vespertilio fuscus*), LIGHT BROWN. 7. FUR HAIR OF THE COYPU (*Myocastor coypus*), BROWN. 8. TIP OF THE FUR HAIR OF THE MUSKRAT (*Fiber zibethecus*), LIGHT BROWN. 9. PROTECTIVE HAIR OF THE FUR SEAL (*Callorhinus alascensis*), BROWN.

never make their appearance. This looks again as though we were dealing with a single species of mammal, though, as has been pointed out, such major variations in medulla form do not occur in any specific relationship among the *Infrahominidae*. The closest structural approach made to human hair shafts is to be found in the hairs of the lower *Primates,* where, as notably in the cases of the Hoolock gibbon, gorilla and Schweinfurth's chimpanzee, the approach is close indeed.

Pigmentation of Infrahominid Hair

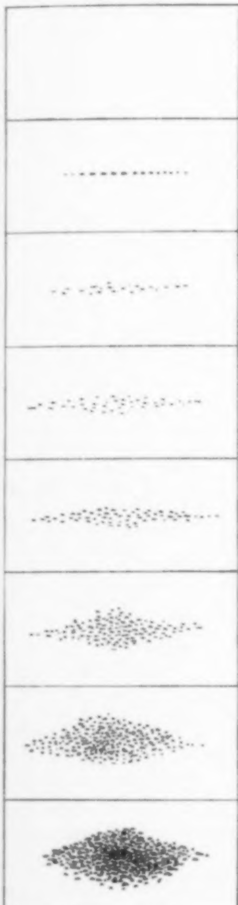
In mammalian hair in general the color is produced by pigmentary substances within the cortex or medulla of the hair shaft and, though but seldom, by pigment secretions from skin glands upon the outer surface of the cuticular scales. No matter how the color of a hair is produced, it may be modified by the way in which the light is reflected from and refracted by the keratized cells of the cortex and medulla and by the cuticular scales.

In the hairs of the infrahominid mammals the pigmentary materials may be in the form of discrete granules, large amorphous masses or diffuse stain. The granules are found in and among the elongate cells of the cortex and in the medullary column. The large amorphous masses occur almost entirely in the medullary column, though sometimes the granules of the cortex may become agglomerated into somewhat similar masses. The diffuse stain colors the cortical cells or the elements of the medulla, but does not stain the cuticle (this offers a useful criterion for judging whether the hair shaft has been artificially colored, in which case the cuticular scales are stained). Pigment, elaborated by skin glands and secreted upon the outer surfaces of the cuticular scales, is comparatively rare as a hair shaft color, being found, for example, on the hairs of the flanks and base of the tail of the ermine species (*Mustela*) where it tints those portions of the white winter pelage a pale yellow.

Fig. 13, 2 to 9, shows several characteristic modes of distribution of pigment granules and masses in the hairs of infrahominid mammals, compared with the cortical pigment granules of the hairs of humans (Fig. 13, 1). Pigmentation characters in the *Infrahominidae* are related to species and not primarily to hair color, though there seems to be evidence (now being accumulated) that some sort of problematical color association of a secondary kind does exist. In hair shafts certain structural and distributional variations in pigmentation exist along the length of the same shaft. The pigmentation at the basal portion of the shaft may be quite different from that midway in its length, and this, in turn, different from that found at its tip. In some species as many as seven appreciably different kinds of pigmentation characters may be seen (Fig. 14). A closer study of the pigmentation of hair shafts indicates that, in the first place (ignoring for the time the modifying effects of reflection and refraction), the color of the hair depends upon the size of the pigment bodies (whether they are disjunct granules or masses), and in the second place, to their numbers in cortex or medulla. An examination of the individual granules in the cortex shows that all shades of brown, from a light straw yellow-brown to almost a black, accompany a progressive increase in the size of the granules. Many factors unite to modify these brown colors, such as distance from the medulla, character of the medulla, presence of diffuse stain in the cortex and the like.

Pigmentation of Hominid Hair

The pigmentation of human hairs differs from that of the infrahominid hairs in two particulars: first, the pigment is



PIGMENT GRANULE PATTERNS	VERNACULAR COLOR NAMES	TECHNICAL COLOR NAMES
	WHITE	WHITE
	LIGHT BUFF	CARTRIDGE BUFF 19'' YO-Y f
	DARKER BUFF	CREAM BUFF 19'' YO-Y d
	YELLOWISH BROWN	ISABELLA COLOR 19'' YO-Y i
	MEDIUM BROWN	BENZO BROWN 13'''' OY-O i
	DARK BROWN	FUSCOUS BROWN 13'''' OY-O k
	VERY DARK BROWN NEARLY BLACK	FUSCOUS BLACK 13'''' OY-O m
	BLACK	BLACK

FIG. 16. THE RELATIONSHIP BETWEEN COLOR OF HUMAN HEAD HAIR AND THE PIGMENT GRANULE PATTERNS IN THE CORTEX OF THE HAIR SHAFT. THE TECHNICAL DESIGNATIONS OF THE COLOR VALUES AS INDICATED IN THE COLUMN ON THE RIGHT ARE TAKEN FROM RIDGWAY'S "COLOR STANDARDS AND COLOR NOMENCLATURE."

present as diffuse stain or as granules (or both), but the granules are not agglomerated into such amorphous masses; and second, it is restricted to the cortex of the shaft and but seldom appears in the medulla, and only in one or two instances known to the writer has it appeared in the keratin of the cuticular scales. Cortical granules and cortical diffuse stain (one or both together), then, account for the hues of human hair.

The pigment granules of the cortex of human head hair are spherical, ovoid or ellipsoid (Fig. 10, left, and Fig. 15, 1), whereas in other mammals variously shaped granules are encountered (Fig. 15, 2 to 9), though ovoid granules are also quite common. This is of use in identifying minute fragments of hair

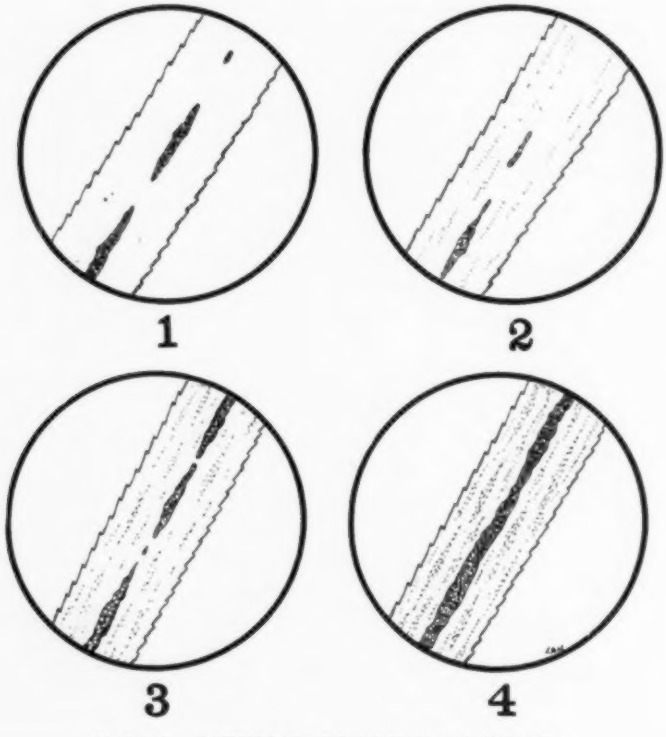


FIG. 17. CORTICAL PIGMENT GRANULES

IN HUMAN HEAD-HAIR SHAFTS, SHOWING THE RELATION OF THEIR NUMBERS AND ASSOCIATIONS TO THE COLOR OF THE HAIR. EACH MICROGRAPH REPRESENTS AN OPTICAL LONGITUDINAL SECTION ALONG THE SHAFT IN THE REGION OF THE MEDULLARY COLUMN. 1. HAIR OF AGED SWEDE, WHITE; FEW OR NO PIGMENT GRANULES. 2. HAIR OF LITHUANIAN, CREAM BUFF (RIDGWAY 19″ YO-Y d). 3. HAIR OF SOMALI, BENZO BROWN (RIDGWAY 13‴ OY-O i). 4. HAIR OF PREDYNASTIC EGYPTIAN, FUSCOUS BROWN (RIDGWAY 13⁗ OY-O k).

shafts, the scales of which may have disappeared and the medullas become distorted. At least, it may serve to assure the microscopist that he is dealing with a fragment of an infrahominid mammal rather than of a human being.

In hominid mammals, unlike the infrahominid, the pigment granules of the cortex of the hair are very definitely associated with the color of the hair, and the larger and more dense their aggregations, the deeper the hue of the shaft. The relations between these granule characteristics and the colors of the hair are shown in the table (Fig. 16). These color values may be altered by the presence of the diffuse stain which, under the microscope, by transmitted light is found to be of a lighter or darker yellowish hue. Where cortical pigment granules are few in numbers they are found aligned in slender rows of single sequence, and as they increase in numbers and give a darker hue to the hair shaft, they become grouped into lenticular associations, and these patterns become progressively and regularly more ovoid and their component granules more closely packed until the patterns seen in the black hairs are reached. The granule patterns vary widely, then, in shape, and this variation is associated with the

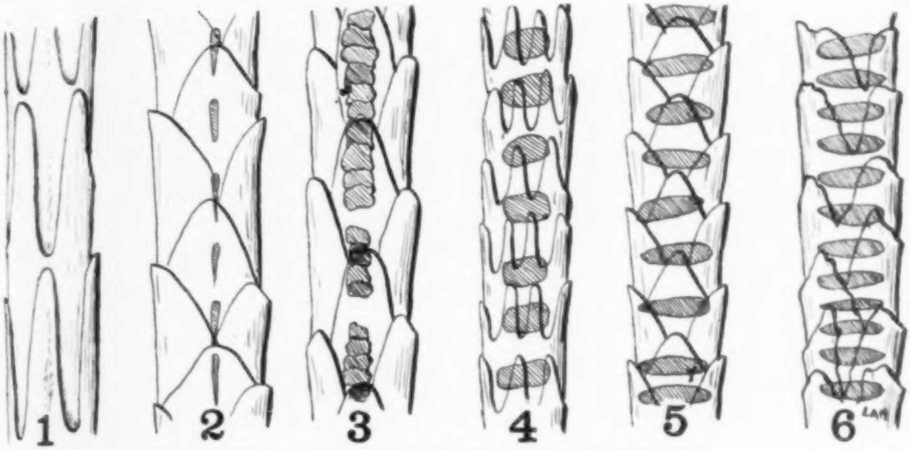


FIG. 18. SIX FUR HAIRS OF COMMERCE

SHOWING THE CHARACTER OF THE CUTICULAR SCALES AND MEDULLAS USED IN IDENTIFICATION. THESE ARE ARRANGED, ALSO, FROM ONE TO SIX, IN THE ORDER OF THEIR DURABILITY FROM THE STANDPOINT OF WEAR WHEN ON GARMENTS, REGARDING THE SEA OTTER FUR (ONE OF THE MOST DURABLE) AS 100. NOTE THAT THE DURABILITY OF A FUR STANDS IN INVERSE RELATIONSHIP TO THE EXPANSE OF THE MEDULLA. THUS, THE SEA OTTER HAIR SHAFT POSSESSES LITTLE OR NO MEDULLARY COLUMN, WHEREAS THE RABBIT AND HARE HAIR SHAFTS POSSESS A VERY LARGE ONE. ALL SHAFTS HAVE BEEN MAGNIFIED TO THE SAME SIZE. 1. SEA OTTER, DURABILITY 100. 2. RACCOON, 65. 3. LYNX, 25. 4. CHINCHILLA, 15. 5. EUROPEAN MOLE, 07. 6. RABBIT OR HARE, 05.

color of the hair and not with race. But here again are encountered slight variations which are problematical and which are, therefore, being further studied together with those variations of medullas and cuticular scales to which allusion has already been made.

In respect of the granules themselves, they range from a little less than 0.20 microns to a little more than 1.25 microns, along their major axes, and their color depth increases with their size. The largest granules were found in the hairs of members of the Bantu tribes (Negroid group), and in the light yellow hairs of the Norwegians.[9] This is indicative of the general status of the granules with respect to size, the smallest being found in the lightest hairs, the largest in the darkest. Fig. 17 shows the appearance of four hair shafts of colors from light to dark and their characteristic pigment granule patterns. Wherever diffuse cortical pigment is present in the hair shaft, the warm tones of reddish, coppery and Titian hues are produced. The more granules (with this combination) the more brownish and Titian, and the fewer granules the more clear orange-red and metallic is the color.

With respect to the application of the study of the microscopic structures of hair much might be said, did the limits of this paper allow it. It may be briefly pointed out, however, that wherever an examination of hair shafts is necessary to determine the species source of samples (in the case of infrahominid hairs) a knowledge of the structural elements of hairs is of the greatest value. In the fur and fabric industries, for example, microscopic examinations are often desirable. It has been pointed out previously in this paper how a clipped may be distinguished from an unclipped fur,

[9] L. A. Hausman, "The Pigment Granules of Human Head Hair, A Comparative Racial Study," *Am. Jour. Phys. Anthrop.*, 12: 273, No. 2, October–December, 1928.

and what the microscope tells us about the reason for the superior durability of the latter. A glance at Fig. 18 will show how a microscopic comparison of cuticular scales and medullas can help in identifying an unknown hair used in furs or fabrics.

A hair may be clipped and dyed and its cuticular scales may even be altered by corrosive reagents, but the medullary column, or at least elements of it, remain the same, as do also the pigment granules in their characteristic forms and patterns. These structures are of the highest diagnostic value. In Fig. 8, 3, note how the genuine otter and nutria hairs (taken from two neck pieces) give up at once the secrets of their origin. Yet both furs were bought for genuine otter. Note that the hair shafts differ not only in diameter but also in granulation and in the characters of their medullas. Their scales likewise (here not shown, since the hair shafts were cleared in oils) differ, and would have revealed this difference under proper treatment.

It must be remembered, however, in all hair shaft comparison examinations, that the same parts of the shafts under comparison must be used, since pigmentation, medulla and scale characters may differ from end to end of the hairs. Likewise it must be made certain that the hairs were taken from the same general regions of the bodies, for in some cases regional differences exist, as has been shown, for example, with respect to the duckbill (*Ornithorhynchus anatinus*).[3]

In making comparisons of minute structures, the comparison ocular proves to be the *sine qua non* of microscopical appliances. This is an optical device, attachable to two identical microscopes, as shown in Fig. 19, below, which gives one such a view of the objects under examination as is shown in Fig. 8, 3, where the two objects are brought close

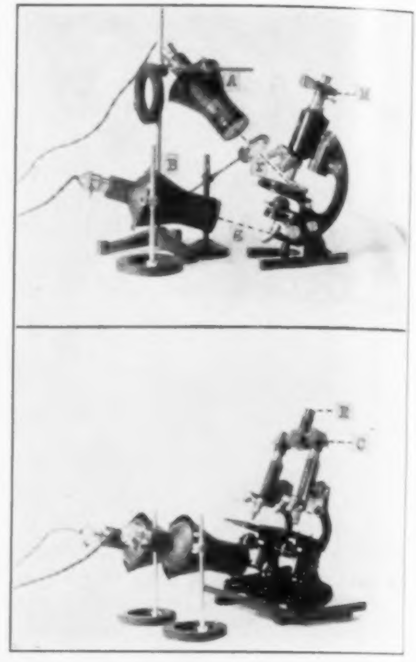


FIG. 19. ENSEMBLE OF APPARATUS FOR THE EXAMINATION OF HAIR SHAFTS BY DICHROMATIC ILLUMINATION. *Above: A*, LAMP DELIVERING THROUGH ITS RED GLASS SCREEN, THE RED LIGHT *r* FOCUSED UPON THE OBJECT THROUGH A BULL'S EYE CONDENSER. *B*, LAMP DELIVERING THROUGH ITS SCREEN GREEN LIGHT, *g*, WHICH IS THROWN UP THROUGH THE TRANSPARENT PARTS OF THE OBJECT BY THE SUBSTAGE MIRROR. *M*, OCULAR MICROMETER. *Below:* APPARATUS FOR COMPARISON OCULAR EXAMINATION OF HAIR SHAFTS WHERE CLOSE COMPARISON OF KNOWN AND UNKNOWN SAMPLES IS NECESSARY. *C*, COMPARISON OCULAR YOKE. *E*, EYE LENS OF OCULAR GIVING SUCH AN IMAGE AS THE ONE SHOWN IN FIG. 8, 3.

together, in the same field of vision magnified to the same extent and lighted in the same way. The addition of a micrometer to the eyepiece makes possible accurate measurements also. Many secrets hidden from the unaided eye have been made to yield themselves up under this sort of inescapable scrutiny.

For, the examination of cuticular scale forms and medullas simultane-

ously, as well as for the study of minute sculpturings on the scales themselves, the writer has devised the assemblage of apparatus shown in Fig. 19, above. By means of this a hair shaft under examination is illuminated at the same time with beams of light of two colors. By employing this sort of dichromatic illumination it is possible to invest some structures in the object with one color and other structures with its complementary color, and thus bring out strikingly by contrast the relationships of the two. Thus, as in Fig. 19, above, the opaque parts of the object on the stage would be viewed by reflected red light, whereas the transparent parts of the same object would be seen by transmitted green light. The micrographs in Fig. 18 were drawn as viewed under dichromatic illumination of this sort.

With respect to human head hair under the microscope, the writer believes, in the light of recent studies of the hair shafts, that it is not possible to determine (from the status of the microscopic elements of the hair shaft) the age, sex or race, since these hair shaft elements are so variable in respect to any one individual and since, moreover, what stability of relationships they do show is associated with hair shaft diameter.[10] This with regard to hairs from normal follicles, and not from follicles diseased or abnormal. When it comes to the question of identifying human hairs, having both known and unknown samples with which to make comparisons of the medullas, cuticular scales, pigment granules, cortical cells, status of diffuse stain and shaft diameters, or unusual modifications (perhaps hereditary, and hence diagnostic) of any of these, then the matter is quite different. But even here it must be possible to make comparative studies between the same portions of the hair shafts, and if one has only fragments of hairs it must be known what parts of the complete hair shaft these represent. Sometimes the microscope may help to settle this question.

The technique of preparing hair shafts for the study of their various elements has been described in earlier papers. Fortunately most hair shafts (those not too heavily invested with pigments) are transparent or nearly so, and this simplifies their examination.

Some of the interesting applications of trichology which have been made in the writer's laboratory are: (1) the study of prehistoric South American Indian grave fabrics, in the hope that it would aid in the fixing of a historical date; (2) the study of cave remains of an early North American Indian occupation, in which hairs of the bison were found, which finding extended our knowledge of the range of this species; (3) a similar study which gave new data concerning the range of the black bear; (4) the examination of a man-killing mountain lion's stomach contents in which human hair was present; (5) the comparison of human hairs in certain legal proceedings; (6) the comparison of hairs from furs to determine whether or not these were correctly named; (7) the examination of hairs from a large chicken farm enclosure, to help to fix the blame upon the mammal culprit which was depredating the stock, and hence to indicate the proper trapping methods to be used against him.

It is not always possible, however, for the microscopist to arrive at a satisfactory conclusion, for the microscope reveals a great deal, in that world invisible to our unassisted vision, which is puzzling to us mortals who pass most of our time in looking out upon things in the gross.

[10] The examination of hair in masses may tell much, as can be seen from the literature.

VICTOR CLARENCE VAUGHAN

THE PROGRESS OF SCIENCE

VICTOR CLARENCE VAUGHAN

THE death of Victor Clarence Vaughan has deprived American medicine and public health of a great leader. He was born on October 27, 1851, at Mount Airy, Missouri, and began his teaching connection with the University of Michigan in 1875, as assistant in the chemical laboratory. In 1879 he became lecturer and in 1880 assistant professor of medical chemistry, and in 1883 he was advanced to the professorship. In 1887 he became professor of hygiene and physiological chemistry and director of the newly established hygienic laboratory. To these duties he added, in 1891, that of dean of the medical school. He held this chair and the deanship until 1921 when he retired as emeritus professor.

Retirement from the university did not close his activities. For several years, as chairman of the Medical Division of the National Research Council, he resided in Washington. It was there he wrote his splendid work, in two volumes, on "Epidemiology and Public Health," and in 1926 he produced his living autobiography "A Doctor's Memories." In the fall of that year, with Mrs. Vaughan, he went as delegate to the Medical Congress in the Orient, visiting China, Japan and the Philippines. On his return in the spring of 1927 he suffered an attack from which he never fully recovered.

Dr. Vaughan was president of the Association of American Physicians in 1908 and of the American Medical Association in 1914. He was a member of the National Academy of Sciences and the American Philosophical Society. As an editor he founded the *Physician and Surgeon*, the *Journal of Laboratory and Clinical Medicine*, and served as the first editor of *Hygeia*. During his thirty years of service on the Michigan State Board of Health he did much to spread the growing knowledge of sanitation and public health.

Dr. Vaughan's investigations covered many fields. At first, the examination of water supplies claimed much attention, and in this connection he devised what he termed "the Michigan method" of analysis which made use of the experimental animal as a means of detecting harmful bacteria. His studies on food poisonings were likewise extensive and thorough. He sought the explanation of the germicidal action of normal serum and found it in the complex chemical constituent nuclein. Even more important were his studies upon the nature of the bacterial poisons or toxins. He devised an ingenious "tank" method for growing pathogenic organisms in mass quantities in order to obtain a sufficient amount of the cells for the purpose of studying the bacterial proteins which he was able to break up into two portions, one toxic and the other non-toxic. He utilized these results in formulating a valuable theory bearing upon the nature of hypersensitiveness and of fevers. As an earnest and enthusiastic investigator Dr. Vaughan had few equals. His extraordinary capacity for writing found expression in more than two hundred publications, not including his more pretentious works, on physiological chemistry, on ptomaines and leucomaines, on cellular toxins, on protein split products, on infection and immunity and on epidemiology.

At the outbreak of the Spanish War Dr. Vaughan volunteered his services and saw active service at Santiago where he contracted yellow fever. The most deplorable fact in connection with that war was the outbreak of serious disease among the troops in the different concentration camps. Laboratory methods were non-existent in the camps, and the

PROFESSOR OWEN WILLANS RICHARDSON

prevailing disease was called indigestion, malaria or typho-malaria, rarely by its true name—typhoid fever. At the close of the war a commission, consisting of Majors Walter Reed, V. C. Vaughan and E. O. Shakespeare, was appointed to investigate the outbreak. The final report of that commission was prepared by Dr. Vaughan, the only surviving member. It was a classical contribution to the epidemiology of typhoid fever. Upon our entry into the late war, Dr. Vaughan was again called upon to give his services. As one of the board in charge of the communicable diseases in our camps, he served with ability and distinction, receiving the rank of colonel, the Distinguished Service medal and the decoration of the French Legion of Honor. More recently he was the recipient of the Kober medal. His work during the two wars brought him full recognition as a leading epidemiologist. As a member of the National Research Council which came into being at the request of President Wilson, Dr. Vaughan participated in the work of that body by his wise counsel and his vast experience.

It is as an instructive and inspiring teacher that Dr. Vaughan will be remembered by the thousands of students who had the opportunity and privilege of listening to him. He freely drew upon his experiences in life and by his masterly presentation made the lectures interesting and forcible.

Unquestionably the greatest service which he rendered to the cause of medical education came during his tenure of the deanship. At the time that he entered this office the new laboratory methods of instruction were just coming into their own. With his clear foresight he recognized the importance of having productive scientific men upon the faculty, and it was this fact which enabled him to get together men of outstanding ability, thus placing the medical school of the university in the front rank of the schools in the country.

Dr. Vaughan's interest in the investigations of his colleagues was not less than that in his own researches. He lived, so to speak, in the laboratory and was never so happy as when a new fact or result rewarded his work. He loved his fellow men and freely gave of his time and energy. As a scientist and educator he was among the first. He has left an enduring impress in both fields. A great leader, a constructive thinker and a broad idealist is gone.

FREDERICK G. NOVY

PROFESSOR OWEN WILLANS RICHARDSON, NOBEL LAUREATE

THE award of the 1928 Nobel Prize in physics to Professor Owen Willans Richardson, of King's College, London, is a matter of particular interest and gratification to Americans because a considerable part of the work for which the award has been made was done at Princeton during Professor Richardson's residence of more than six years in this country, and also because of the benign influence which Professor Richardson's presence with us has had upon the course of physical research on this side of the Atlantic. It is appropriate in these circumstances to make this American episode in Professor Richardson's life the central theme of this brief biographical note concerning him.

In the summer of 1906 the late Dean Henry B. Fine, of Princeton University, visited Sir J. J. Thomson (then Professor Thomson), of Cambridge University, and asked him to recommend, from the large group of brilliant investigators then working under his direction in the Cavendish Laboratory, a candidate for a research professorship in physics which had been recently established at Princeton. An attempt was to be made to transplant from the ferment of physical

research, then so active in the Cavendish Laboratory, a culture which, it was hoped, would engender a similar ferment in America. The "culture" selected and recommended by Professor Thomson was the subject of this note.

Professor Richardson, then a fellow of Trinity College, had at that time worked for some years in the Cavendish Laboratory and had devoted himself particularly to an investigation of the emission of electricity (electrons) from hot bodies (glowing filaments). In the prosecution of this investigation he had distinguished himself by his exceptional ability as both an experimental and a theoretical physicist. He had discovered how the rate of emission from a hot body varies with the body's temperature, had given mathematical expression to this relation—thenceforth to be known as Richardson's Law—and had put forth a theory of the phenomenon in which the emission of electrons from an incandescent filament was pictured as similar to the evaporation of atoms from a liquid on solid surface. He had introduced into physics the important concept of a "work function," a measure of the work required to detach an electron from a metal, as a necessary feature of this theory. These things he had accomplished at the age of 27, and at a time when experimental facilities for this kind of work were much less adequate than they are to-day. Professor Thomson paid a great compliment to Princeton University in recommending such a man for the newly established professorship.

Professor Richardson arrived in Princeton in the autumn of 1906 accompanied by his bride of a few months, the sister of his friend and colleague at Cambridge, Professor Harold A. Wilson, now of Rice Institute; and was followed shortly by his own sister, now the wife of Professor Oswald Veblen, of Princeton. Sir James Jeans (then Professor Jeans) had come to Princeton a year earlier, and during the academic year 1906–07 graduate students at Princeton had the benefit of contact with both these eminent English physicists.

At Princeton, Professor Richardson pressed forward with great vigor further investigations in "thermionics," as he named his chosen field. Alone or in collaboration with others, he made at Princeton the first reliable observations upon the so-called "cooling effect," which is the analogue in thermionics of the cooling by vaporization with which we are familiar in the case of liquids. In collaboration with Professor H. L. Cooke, he made the first observations upon the reverse effect, the heating of filaments through the absorption of electrons. These experiments confirmed the theory which was serving as a guide to the investigations, and yielded data from which the values of thermionic work functions could be computed. The theory was further confirmed by the demonstration that the electrons leaving a hot body have a Maxwellian distribution of velocities, and that their mean kinetic energy is the same as that of an assemblage of gas molecules at the same temperature. He investigated also the emission of positive ions from metallic filaments and from salts. On the theoretical side he elaborated the theory of thermionic emission to the greatest generality consistent with the principles of thermodynamics.

While thermionics occupied the focus of Professor Richardson's attention during this period, his activities were by no means restricted to this field. In addition he carried out or directed investigations in radioactivity and in X-ray phenomena, and especially important ones in photoelectricity. In these latter he impressed on physicists the importance of contact differences of potential in experiments of this kind. His theoretical interests also were diversified; we

find among his papers contributions on the theory of magnetism and on the structure of the ether. The total number of papers bearing Professor Richardson's name as sole or joint author and published during these six years is no less than thirty-four—a surprisingly great number in any circumstance, but particularly so when it is considered that during the first two of these years physics at Princeton was lodged in the ancient and poorly equipped Science Building; the Palmer Laboratory was not completed until 1908.

Among Professor Richardson's students during these years were Professor A. H. Compton, of the University of Chicago, also a Nobel laureate; Professor K. T. Compton, the able successor of Professor Richardson as director of research in physics at Princeton; Dr. C. J. Davisson, of the Bell Telephone Laboratories, New York, whose wife is another of Professor Richardson's sisters; Professor A. G. Shenstone, of Princeton University, and Professor K. K. Smith, of Northwestern University.

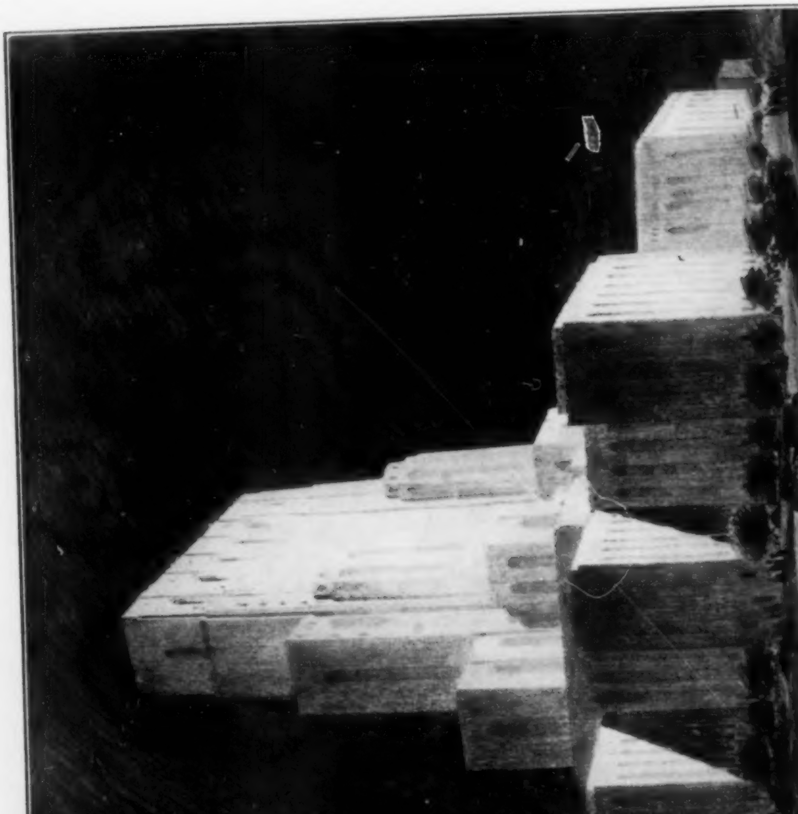
Professor Richardson is remarkably conversant with all the great volume of experimental and theoretical work which has followed upon the discovery of X-rays and the isolation of the electron. His book "The Electron Theory of Matter," written at Princeton and published in 1914, is the most comprehensive summary we have of this newer physics, as of that date.

Professor Richardson was an active and highly valued participant in the meetings of the American Physical Society, and spoke often before other scientific bodies as well. The American Philosophical Society elected him to honorary membership; and it was also during his Princeton days that he became a Fellow of the Royal Society of London.

The conditions under which Professor Richardson worked at Princeton, particularly after 1908, were in many respects ideal, and yet it can not be said that he was ever completely happy in the American environment. He disliked the hot New Jersey summers which interrupted his work and drove him and his family from Princeton to the coast of Maine. But quite apart from climatic considerations he longed to return to England, and did so when he was offered the Wheatstone professorship of physics at King's College, London. He returned to England with his wife and three children in December, 1913. His leaving was a great loss to physics in America and a matter of keen regret to the many friends he and his family had made in Princeton and elsewhere in America; but the aim which Dean Fine had in view had been attained; the culture had thriven. A center of research into the newer problems of physics had been established at Princeton. To-day it is one of the most important in the country.

Half a year after Professor Richardson's return to England, Europe was plunged into the world war. His activities, like those of nearly all other European physicists, were deflected from their accustomed channels. During the war he was attached to the British Admiralty to which he rendered valuable service, and yet during this period he managed to bring out a second and revised edition of his "Electron Theory of Matter," and the first edition of his "Emission of Electricity from Hot Bodies." A second edition of this latter treatise was published in 1921.

Professor Richardson's work in thermionics for which he received the Nobel Prize may be said to have ended with his stay at Princeton. Since the war his interests have centered in other problems, in the emission of electrons during chemical reaction, in soft X-rays, in photoelectricity and particularly in spectroscopy. In this last named field he has devoted himself for some years to the



—From a photograph of the architect's drawings

THE NEW YORK HOSPITAL–CORNELL MEDICAL COLLEGE BUILDINGS

ordering and interpreting of the complicated band spectra of hydrogen. In this field, as in that of thermionics, he has made himself preeminent.

In 1924, Professor Richardson resigned the Wheatstone professorship to accept one of the three newly established Yarrow Research Professorships of the Royal Society. His connection with King's College was not, however, severed; he is still the director of research in physics in that institution.

In 1920, Professor Richardson was granted the Hughes Medal by the Royal Society, for his work in thermionics. The following year he served as president of Section A of the British Association, and from 1926 to 1928 he was president of the Physical Society of London. To these and his previous honors and preferments is now added the crowning one bestowed upon him by the Swedish Academy. It is a signal honor, well earned and richly deserved.

THE NEW YORK HOSPITAL–CORNELL MEDICAL COLLEGE ASSOCIATION

MATERIAL prosperity has always carried with it an implied obligation to advance the scientific, social, cultural and artistic standards. One of the most promising indications that America is recognizing this obligation and is preparing to meet it in keeping with her great means is the new medical center now under construction by the New York Hospital-Cornell Medical College Association.

This project bids fair to become one of the most far-reaching and important undertakings for the advancement of medical science and of human welfare. It will bring together, under unified control, one of the nation's foremost hospitals, with a record of a century and a half of distinguished service, and one of its leading schools of medicine.

The buildings which are now being erected by the Association, on a site covering three square blocks along the East River in New York City north of Sixty-eighth Street, are designed to afford complete coordination of all activities in medical education, research and care of the sick. In the early stages of this development, its activities are manifest chiefly in terms of structure and facilities, but it is realized by the Association that the true importance of these things lies not in themselves, but in the opportunities they afford to distinguished medical scientists and practitioners for the advancement of science and practice in medicine.

In the central section of the development will rise the main building of the hospital, twenty-four floors in height. On the West, it will be flanked by the laboratories of the medical sciences, five in number, extending for two blocks along York Avenue. Along the river, and connected with the main hospital building, are to be three special clinical institutes. One will be devoted to maternity work and will take over the service of the Lying-In Hospital. Another will be a psychiatric institute, for which Payne Whitney, whose gifts in great measure made the whole project possible, made special provision in his will. The third will be a pediatric institute, devoted to research and the treatment of children's diseases.

Although it has no formal connection with the new center, the presence of the Rockefeller Institute for Medical Research as its immediate neighbor on the South is significant, as it will bring into close association men in both institutions who are working on allied problems in medical science.

From the standpoint of medical research, the center will afford unusual opportunities for cooperative investiga-

—*Bacrach*

PROFESSOR AUGUST KROGH

WHO BY SPECIAL INVITATION GAVE THE PRINCIPAL ADDRESS AT THE INTERNATIONAL CONGRESS OF PHYSIOLOGY. DR. KROGH, WHO IS DIRECTOR OF THE ZOOPHYSIOLOGICAL LABORATORY OF THE UNIVERSITY OF COPENHAGEN, WAS AWARDED A NOBEL PRIZE FOR HIS WORK ON THE PHYSIOLOGY OF THE CAPILLARIES.

tions bringing together in daily contact men who are working in almost every field of medicine.

The center will provide facilities for the treatment of 1,000 bed patients and approximately the same number of outpatients daily. The teaching, research and hospital staff, undergraduate and graduate students, and nurses and employees, will number from 1,500 to 2,000 persons.

Between Seventieth and Seventy-first Streets, the Association is building a nurses' home to house 500 student and graduate nurses, an employees' dormitory, and a service building garage and power plant designed to serve the entire center.

THE DR. WALTER B. JAMES MEMORIAL LABORATORY FOR BIOPHYSICS

A NEW laboratory is being completed for research in biophysics at the Biological Laboratory of the Long Island Biological Association at Cold Spring Harbor. The completion of this building marks not only a step forward by that laboratory, but gives indication of the strength of a new viewpoint which will doubtless find expression in an increasing number of institutions.

At Cold Spring Harbor the laboratory has been established from the point of view that it shall be a real physical laboratory, equipped with all the facilities of a modern physical institute, for work with problems in biology. The primary aim of the laboratory is therefore to develop physical apparatus and methods of value to biology and to carry on research in those fields in physics in which work is required for the purposes of biology.

As a secondary aim, the laboratory will place at the disposal of visiting biologists various physical apparatus developed at the laboratory or such standard physical apparatus as is available. It is considered that Cold Spring Harbor provides an ideal place for such a laboratory by giving an opportunity for first-hand acquaintance with such apparatus to the large number of investigators from universities and medical schools throughout the country who are in residence at the Biological Laboratory during the summer. It is expected, in this way, that the equipment and findings of the laboratory will be of immediate and unusual value to biologists at large.

The laboratory itself, of which a photograph is reproduced herewith, has been planned and constructed with special attention to safety, and to the control of temperature, vibration and noise. It is one story in height and of simple utilitarian architecture. It includes an X-ray laboratory equipped with a 10 K.W. 140 K.V., kenotron-rectified X-ray generating unit, installation for pumping X-ray tubes and other kinds of vacuum tubes, apparatus for measuring X-rays in the new international r-unit; a laboratory equipped for work with high frequency electric currents; a chemical laboratory equipped with a number of special apparatus especially designed for a study of the chemical action of X-rays, an apparatus for electrometric titration, apparatus for analysis of gases, a spectrophotometer; a mechanics shop with shop equipment and tools for precision work, a carpenter shop and a glass-blowers' shop. There are also a cold room, a photographic room, a filing room and a small library. Provision has been made for the addition of a second story when needed.

The laboratory has been named the Dr. Walter B. James Memorial Laboratory in honor of Dr. James who was for many years an officer of the laboratory and who was president of the Long Island Biological Association at the time of his death. The building was given by Mrs. James in recognition of Dr. James's sustained and reasoned interest in the work of the Biological Laboratory.

THE DR. WALTER B. JAMES MEMORIAL LABORATORY

The laboratory for biophysics is under the immediate charge of Dr. Hugo Fricke, who was appointed to the staff of the Biological Laboratory one year ago. Previously he had been director of the department of biophysics of the Cleveland Clinic Foundation. The technical staff includes an instrument-maker, a radio engineer and a glass-blower. Dr. E. Saxl, of Vienna, is collaborating in research on the electrical capacity and conductivity of biological cells and systems, and Messrs. R. W. Asmussen and A. Hempel-Hansen, of the University of Copenhagen, are cooperating in studies of the chemical action of X-rays.